SEWAGE WORKS JOURNAL

VOL. XXI JULY, 1949 No. 4

Special Features

Effects of Synthetic Detergents—
Rudolfs, Manganelli, and Gellman

Activated Sludge Oxygen Requirements—
Dawson and Jenkins

Sewage Treatment Biology—Lackey

Chemical Manufacturing Wastes—Hess

OFFICIAL PUBLICATION OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Make Plans to Attend

TWENTY-SECOND ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

IN CONJUNCTION WITH

NEW ENGLAND
SEWAGE WORKS ASSOCIATION

STATLER HOTEL

BOSTON, MASS.

October 17-20, 1949

Place Reservations Directly with Hotel

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

YOU NEED BOTH HALVES OF THE SCISSOR

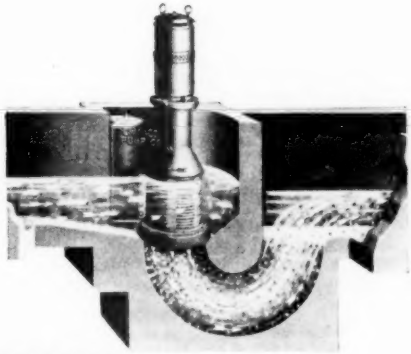
In the CHICAGO Comminutor the cutters and shear bars cut and chop; the channel feeds and holds.

The combination of channel and rotating drum makes the CHICAGO Comminutor the only effective method for cutting and screening sewage solids in the stream.

Engineering details of exclusive CHICAGO Channel Designs for any sewage flow are available to engineers on request.

Over 2000 successful installations prove "You Need Both Halves Of The Scissor."

The CHICAGO Comminutor is always placed in an exclusively designed feeder channel. The hydraulic characteristics are such that accumulating solids cannot clog the drum slots; nor can rope-like material jam the drum. Comminution is rapid and positive. Sub-surface screening is continuous and automatic.



Cross section of a CHICAGO Comminutor channel illustrates a typical design of controlled discharge channel. Sheared small particles must pass through a maximum drum slot width of 3/8 in. Comminuted matter completely settles out in the primary tanks.

CHICAGO PUMP COMPANY

SEWAGE EQUIPMENT DIVISION

2300 WOLFRAM STREET — **CHICAGO 18, ILLINOIS**

Flush Kleen, Screw Feller, Plunger Horizontal and Vertical Non-Clogs Water Seal Pumping Units, Samplers.

Swing Diffusers, Stationary Diffusers, Mechanical Aerators, Combination Aerator-Clarifiers, Comminutors.

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

PRESIDENT

V. M. EHLERS
Chief Sanitary Engineer
State Department of Health
Austin 2, Texas

VICE-PRESIDENT

A. H. NILES
Engineer-Superintendent
Division of Sewage Disposal
Bay View Park,
Toledo 11, Ohio

TREASURER

W. W. DEBERARD
City Engineer
402 City Hall
Chicago, Illinois

EXECUTIVE SECRETARY-EDITOR

W. H. WISELY
325 Illinois Building
Champaign, Illinois

ADVISORY EDITOR

F. W. MOHLMAN
Director of Laboratories
The Sanitary District of Chicago
910 S. Michigan Ave.
Chicago, Illinois

DIRECTORS

Alabama: R. C. BARTON (1951)
Arizona: RUSKIN T. GARDNER (1949)
Argentina: E. B. BESSELIEVRE (1943)*
Arkansas: F. L. MCDONALD (1949)
California: RICHARD D. POMEROY (1950)
Canada: R. J. DESMARAIS (1949)
Central States: GEORGE MARTIN (1951)
Dakota: ROY G. SPIEKER (1949)
Federal: LAWRENCE M. FISHER (1950)
Florida: B. F. BORDEN (1950)
Georgia: GILBERT R. FRITH (1950)
Inst. San. Eng. (Eng.): G. S. MCDONALD (1950)
Inst. Sew. Pur. (Eng.): W. F. FREEBORN (1950)
Iowa: JOHN L. STRELOW (1950)
Kansas: E. E. MILTNER (1951)
Kentucky-Tennessee: JAMES ELLIS (1949)
Maryland-Delaware: C. E. KEEFER (1951)
Michigan: W. F. SHEPHARD (1949)
Missouri: A. H. WYMORE (1951)
Montana: K. L. CHRYSLER (1950)
New England: F. L. FLOOD (1951)
New Jersey: L. J. FONTENELLI (1951)
New York: G. E. SYMONS (1951)
North Carolina: GEORGE S. RAWLINS (1949)
Ohio: B. M. MCDILL (1951)
Oklahoma: FRANK S. TAYLOR (1950)
Pacific Northwest: C. M. HOWARD (1950)
Pennsylvania: L. D. MATTER (1949)
Puerto Rico: ALBERTO HERNANDEZ (1950)
Rocky Mountain: L. O. WILLIAMS (1951)
Switzerland: W. DARDEL (1951)
Texas: J. H. SORRELLS (1951)
Virginia: L. L. HEDGEPETH (1950)
West Virginia: K. S. WATSON (1950)
At Large: A. F. DAPPERT (1949)
At Large: DON E. BLOODGOOD (1950)
At Large: CARL E. GREEN (1951)
W. and S. Wks. Mfgrs.: J. W. VAN ATTA (1949)
W. and S. Wks. Mfgrs.: R. S. RANKIN (1950)
W. and S. Wks. Mfgrs.: W. A. HARDENBERGH (1951)
Ex-Officio: G. S. RUSSELL
Ex-Officio: M. M. COHN
Ex-Officio: EARNEST BOYCE
Ex-Officio: F. W. GILCREAS
Ex-Officio: WILLEM RUDOLFS
Ex-Officio: W. J. ORCHARD *

* Successor not yet designated.

SEWAGE WORKS JOURNAL

REG. U. S. PAT. OFF.

A bimonthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

325 Illinois Bldg., Champaign, Ill. Send all manuscripts, advertising copy, subscriptions, address changes, etc. to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $3.00 per year.

Non-members: U. S. and Canada, $5.00 per year; other countries, $6.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States, $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

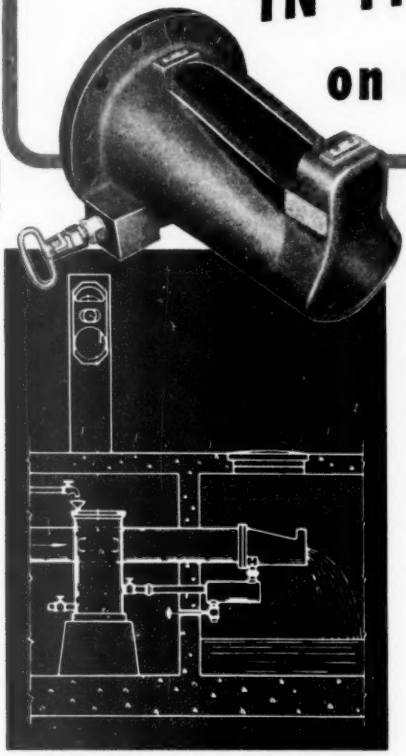
MAILING PERMIT

Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in part 4, Section 538, P. L. & R., authorized October 4, 1945.

INDEX SERVICE

Sewage Works Journal is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

ARE YOU "IN THE KNOW" on OPEN FLOW?



Builders Type M Totalizer-Indicator-Recorder connected to Kennison Open Flow Nozzle.

BUILDERS PRODUCTS

Venturi, Propelofio and Orifice Meters
Kennison Nozzles • Venturi Filter Controllers and Gauges • Conveyofio Meters • Type M and Flo-Watch Instruments • Wheeler Filter Bottoms • Master Controllers
Chlorinizer-Chlorine Gas Feeders • Filter Operating Tables • Manometers
Chronofio Telemeters

BUILDERS KENNISON NOZZLE

is specially designed for metering open flow of raw sewage, trade wastes, raw and digested sludge, and final effluent. In partially filled pipes and open channels where low head conditions and widely varying flow rates are encountered, this nozzle meters accurately and dependably. Its accuracy is not dependent on field construction. Kennison Nozzles with proper Builders Instruments have proved eminently successful in this type of service and have contributed to the efficiency of many sewage plants throughout this country and abroad. For complete information and Bulletin 334A, address Builders-Providence, Inc., (Division of Builders Iron Foundry), Providence 1, R. I.

FEATURES

1. **Wide range efficiency**
2. **Accuracy on low head installations**
3. **Clear through-way to avoid clogging by debris**
4. **Flow velocity increase to promote self-scouring**
5. **Open top for easy inspection and cleaning**
6. **Vent cleaner for cleaning piezometer hole**
7. **Low head loss**
8. **Economical installation**

BUILDERS PROVIDENCE *Instruments*

FSWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
ALEX O. TAYLOR, *Secretary*
Engineering Ext. Service
Alabama Polytechnic Institute
Auburn, Alabama

Argentina Society of Engineers, Sanitary Engineering Div.
EDMUND B. BESSELIEVRE, *FSWA Contact Member*
c/o The Dorr Company
570 Lexington Ave.
New York 22, N. Y.

Arizona Sewage and Water Works Assn.*
MRS. HELEN ROTTHAUS, *Sec.-Treas.*
c/o Sanitary Engineering Div.
Arizona State Dept. of Health
Capitol Building
Phoenix, Ariz.

Arkansas Water and Sewage Conf.*
DR. HARRISON HALE, *Sec.-Treas.*
118 Chemistry Bldg.
Fayetteville, Ark.

California Sewage Works Assn.
L. H. COOK, *Sec.-Treas.*
Box 696
Menlo Park, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Ontario Dept. of Health
Sanitary Engineering Div.
Toronto 8, Ontario, Canada

Central States Sewage Works Assn.
PAUL W. REED, *Sec.-Treas.*
1098 W. Michigan St.
Indianapolis 7, Ind.

Dakota Water and Sewage Works Conf.
*North Dakota Section**
JEROME H. SVORE, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.
*South Dakota Section**
W. W. TOWNE, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health
Pierre, S. Dak.

Federal Sewage Research Assn.
RALPH C. GRABER, *Sec.-Treas.*
c/o USPHS
69 W. Washington Street
Chicago 2, Ill.

Florida Sewage Works Assn.
PERRY M. TEEPLE, *Sec.-Treas.*
Florida State Board of Health
P. O. Box 210
Jacksonville, Fla.

Georgia Water and Sewage Assn.*
L. E. WALLER, *Sec.-Treas.*
Rt. 12, Box 264
Atlanta, Ga.

Iowa Sewage Works Assn.
LEO HOLTKAMP, *Sec.-Treas.*
E. Ohio St.
Webster City, Iowa

Institution of Sanitary Engineers
ERNEST BALSOM, *Secretary*
8, Cotswold Rd.
Belmont, Surrey,
England

Institute of Sewage Purification
J. H. GARNER, *Federation Contact Member*
28 Aberford Road
Wakefield, Yorks, England

Kansas Sewage Works Assn.
DWIGHT F. METZLER, *Sec.-Treas.*
c/o State Board of Health
Marvin Hall
University of Kansas
Lawrence, Kan.

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
R. PAUL FARRELL, *Sec.-Treas.*
420 Sixth Ave., N.
Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
L. C. ELDRIDGE, *Secretary*
c/o Baton Rouge Water Wks. Co.
131 Lafayette Street
Baton Rouge, La.

Maryland-Delaware Water and Sewerage Assn.*
MISS E. VIRGINIA GIPE, *Sec.-Treas.*
c/o State Dept. of Health
2411 N. Charles St.
Baltimore, Md.

Michigan Sewage Works Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334 Administration Bldg.
Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
c/o State Office Bldg.
Jefferson City, Mo.

Montana Sewage Works Assn.
H. B. FOOTE, *Sec.-Treas.*
Div. of Sanitary Engineering
State Board of Health
Helena, Montana

New England Sewage Works Assn.
WALTER E. MERRILL, *Sec.-Treas.*
c/o State Dept. of Health
511-A State House
Boston, Mass.

New Jersey Sewage Works Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 283
Manville, N. J.

New York State Sewage Works Assn.
RALPH C. SWEENEY, *Sec.*
c/o State Dept. of Health
19 E. Main St.
Rochester 4, N. Y.

North Carolina Sewage Works Assn.
E. C. HUBBARD, *Sec.-Treas.*
North Carolina State Board of Health
Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conference
G. A. HALL, *Sec.-Treas.*
302 Dept. of State Bldg.
Columbus, Ohio

Oklahoma Water and Sewage Conf.*
H. J. DARCEY, *Sec.-Treas.*
State Dept. of Health
Oklahoma City 5, Okla.

Pacific Northwest Sewage Works Assn.
W. P. HUGHES, *Sec.-Treas.*
City Engineer's Office
Lewiston, Idaho

Pennsylvania Sewage and Industrial Wastes Assn.
B. S. BUSH, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
Kirby Health Center
Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Assn.
ALVAH R. PIERCE, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2853
San Juan 12, Puerto Rico

Rocky Mountain Sewage Works Assn.
CARROLL H. COBERLY, *Sec.-Treas.*
Room 329
1441 Welton St.
Denver 2, Colo.

Swiss Assn. of Water and Sewage Professionals
WALTER DARDEL, *FSWA Contact Member*
Aarberg (Berne), Switz.

Texas Water and Sewage Works Assn.
V. M. EHLERS, *Sec.-Treas.*
501 W. 33rd St.
Austin, Tex.

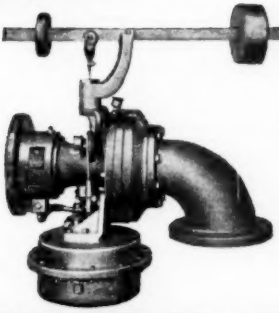
Virginia Industrial Wastes and Sewage Works Assn.
A. H. PAESSLER, *Sec.-Treas.*
815 E. Franklin St.
Richmond 19, Va.

West Virginia Sewage and Industrial Wastes Assn.
R. G. MCCALL, *Sec.-Treas.*
State Department of Health
Rm. 643, State Capitol
Charleston 5, W. Va.

* Sewage Works Section.

Everything's under control—

WITH



Type S
Rate of Flow
Controller

SIMPLEX

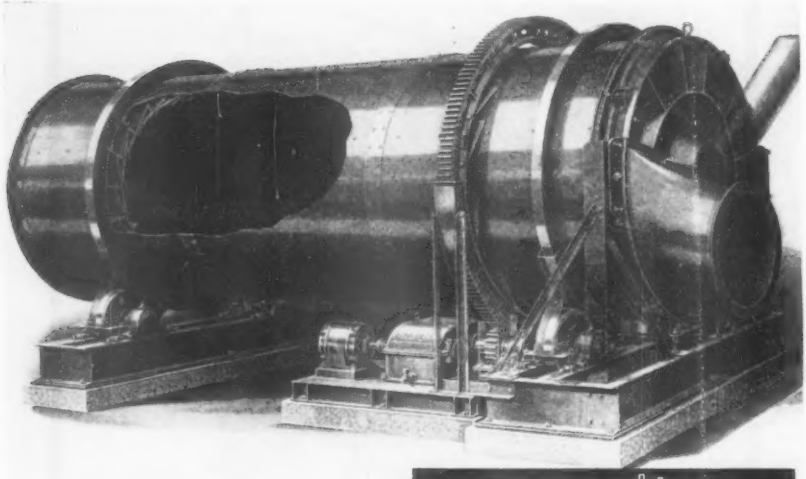
ACCURATELY CONTROLS RATE OF FLOW OVER LONG RANGES!

Of the most advanced, proven design, Simplex Type S controllers meet all requirements of modern filter plants! Look at these unmatched advantages:

- **Compact design, low weight**
- **Small overall dimensions**
- **Ball bearing mounted valve shaft**
- **Hydrostatically balanced, patented guillotine valves**
- **Horizontal or vertical installation**
- **Simple direct action design**
- **Venturi tube type of differential pressure producer**
- **Quick starting from open position**
- **Response to slightest differential pressure**
- **Extreme accuracy of control over long ranges**

For bulletin with full information, write to the Simplex Valve & Meter Co., Dept. 7, 6719 Upland Street, Philadelphia 42, Pa.

SIMPLEX VALVE & METER CO.



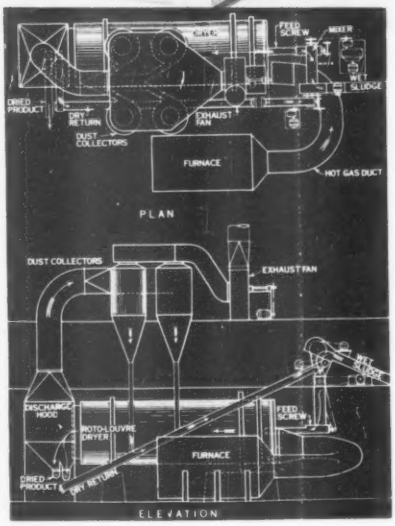
May we demonstrate
LINK-BELT Roto-Louvre
Dryer Performance on Sludge?

The Link-Belt Roto-Louvre Dryer is ideally suited for drying sewage sludge or solids from industrial wastes. Operating upon the principle of convected heat, it offers more efficiency, more uniformity of product, no overheating or scorching of material. It can handle a large volume in a small space.

The Roto-Louvre Dryer percolates hot air through the material—its unique design eliminates cascading of material into an air stream. It reduces degradaton, dust and loss of material through the exhaust.

May we demonstrate to you the performance of the Roto-Louvre Dryer? The Link-Belt Dryer Laboratory is available for test runs to show you exactly what you can do in your own plant. Contact your nearest Link-Belt office to arrange for a test run.

We manufacture a complete line of water, sewage and industrial liquid treatment equipment, such as coarse and fine screens, grit and sludge collectors for grit chambers and settling tanks, scum breakers for sludge digestion, and sludge handling equipment. Send for catalogs.



LINK-BELT
DRYERS AND COOLERS
DRYING PROCESS ENGINEERING

LINK-BELT COMPANY

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8
Offices in Principal Cities

BATTLE CREEK, MICH.

"One of America's Safest Cities"
THE MATHEWS FIREMEN SAY

They never said a truer word, because Battle Creek, Michigan is protected by Mathews Modernized Hydrants—and where Mathews are, there is safety *plus*.

These great hydrants give long, trouble-free service because of their simplicity of design and accessibility for service. All working parts are contained in a removable barrel; if replacement is required, as when the hydrant is knocked over by a truck, a spare barrel can be inserted in a few minutes, and without excavating. The stuffing box plate, cast integral with the nozzle section, prevents water and silt from reaching the operating thread. An iron shield guards the bronze revolving nut against rain and dust. Free and quick operation is assured at all times.

Send for illustrated folder setting forth point by point the many features that make Mathews Modernized Hydrants the shrewdest buy for every safety-minded community.

OTHER MATHEWS FEATURES: Head can be rotated 360° • Replaceable head • Nozzle outlets easily changed • Nozzle levels raised or lowered—no excavating • Drains dry after use • Only one part to lubricate—the operating thread • A modern barrel makes even the oldest Mathews new.

MATHEWS HYDRANTS

Made by R. D. WOOD COMPANY

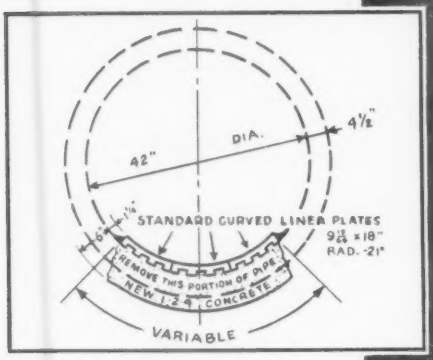
Public Ledger Bldg., Independence Sq., Phila., Pa.

Manufacturers of "Sand Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

Clay Liner Plates

SALVAGE RELIEF SEWER SYSTEM

THE Engineering Department of Cudahy, Wisconsin, recently devised an unusual method of salvaging a non-vitreous relief sewer which had disintegrated from constant attack by sulphuric acid discharged from a nearby drop forge plant. Vitrified Clay Liner Plates were used to replace the invert of the sewer to take care of the high-acid waste material flowing through the line. The sewer arch, which had not been in contact with the waste material, was saved.



Clay Pipe Passes A. S. T. M. Acid Test With Plenty To Spare

Forty-eight hours suspended in fiery solutions of sulphuric, nitric, hydrochloric, or acetic acids . . . that's the rugged A. S. T. M. test for acid resistance! And Vitrified Clay Liner Plates come through without so much as a pockmark! That's the reason Clay is specified by leading engineers the world over for sewerage and waste disposal systems of all kinds. Clay Pipe and Clay Liner Plates are made from nature's own chemically inert material . . . it *never wears out!*

C-4492

WRITE FOR INFORMATION ON YOUR CLAY PIPE QUESTION

NATIONAL CLAY PIPE MANUFACTURERS, INC.

100 N. LaSalle St., Rm. 2100, Chicago 2, Ill.
522 First National Bank Bldg., Atlanta 3, Ga.
703 Ninth and Hill Bldg., Los Angeles 15, Calif.
1105 Huntington Bank Bldg., Columbus 15, Ohio

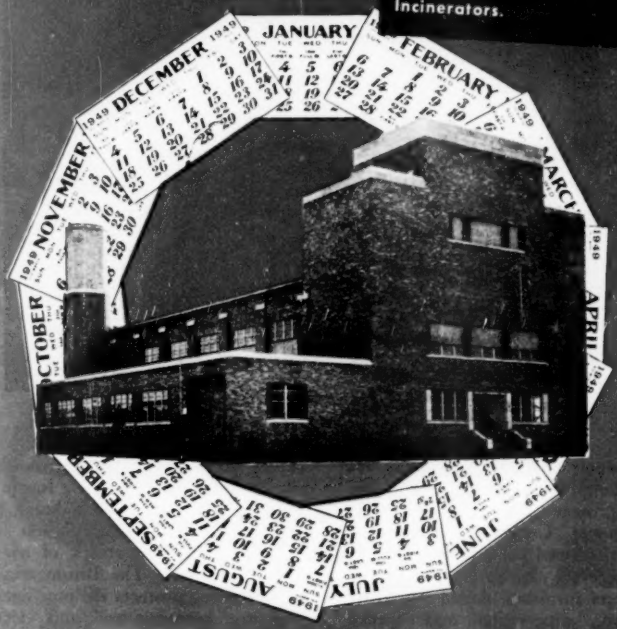
Vitrified

CLAY PIPE NEVER WEARS OUT!

CLAY PIPE

How dependable is a Sludge Drier-Incinerator?

The answer is found in operating logs of sewage plants using Nichols Multiple Hearth Drier-Incinerators.



For instance: the Minneapolis-St. Paul Sanitary District reports runs of 24 hours a day—7 days a week of which the following are illustrative:

May 24, 1946 to March 26, 1947—306 DAYS

April 25, 1947 to March 18, 1948—348 DAYS

NICHOLS ENGINEERING & RESEARCH CORPORATION

70 Pine St. New York 5, N.Y. • 405 Lexington Ave. Pasadena, Calif. • 1477 Hawthorndale St. West, Montreal 25, Canada

"Koppers will handle the coating job from *start to finish.*"

● On water and sewage projects, it's sound, long-range planning to turn the job of protecting the steel pipe over to Koppers Contract Department. Koppers' trained protection specialists will handle the job from start to finish.

Koppers furnishes skilled workmen, competent supervision and special equipment to coat your pipe lines inside and out with Koppers Bitumastic® Enamel.

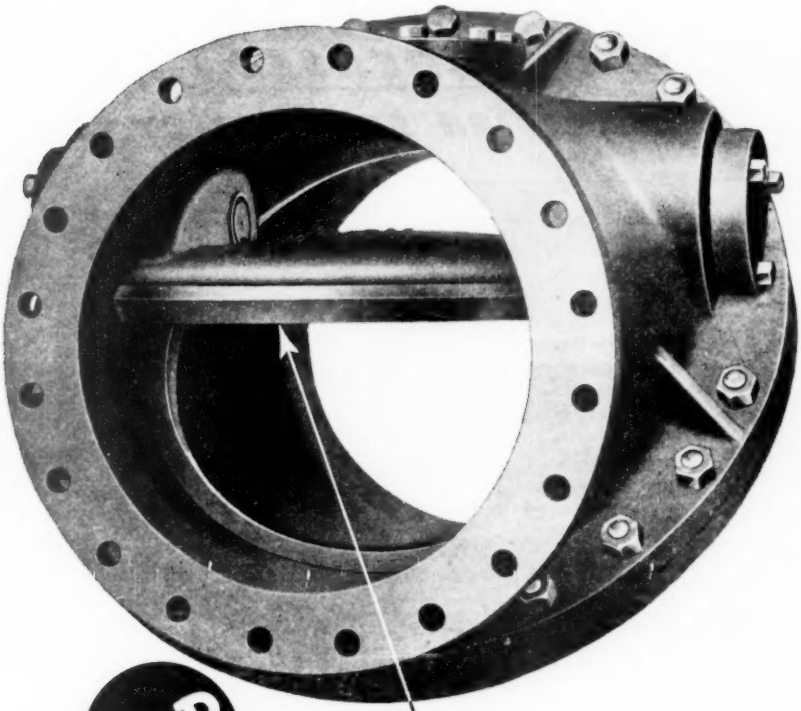
This *permanent* protective coating is processed from coal-tar pitch, a substance that has outstanding records in the battle against corrosion. Inside the pipe, the Bitumastic spun lining prevents rust and tuberculation and guards against the attack of sewage gases and acids. The Bitumastic exterior coating protects the pipe against moisture, corrosive soil and electrochemical reaction.

For long-lasting protection against corrosion . . . for a job done right from start to finish . . . call on Koppers Contract Department.

®T. M. Reg. U. S. Pat. Off.

KOPPERS COMPANY, INC., Dept. 719T, Pittsburgh 19, Pa.

KOPPERS BITUMASTIC ENAMELS



pipe line surging with the cushioned closing of

CHAPMAN

CHECK TILTING DISC VALVES

Cushioned by the effect of the stream on the short flap of the balanced disc, Chapman Tilting Disc Check Valves close smoothly and quietly. Slamming and dangerous pipe line stresses are eliminated . . . maintenance costs reduced. Head losses are cut 65% to 80% as compared with conventional type check valves.

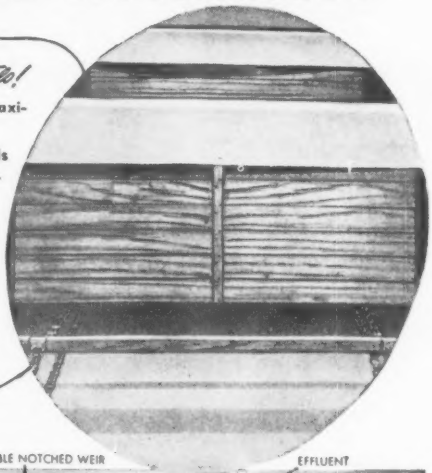
Chapman Tilting Disc Check Valves are obtainable in either iron or steel. For complete information send for catalog No. 30.

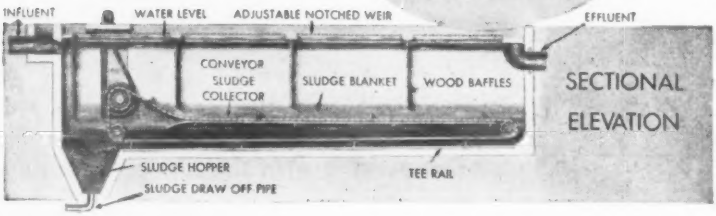
The Chapman Valve Mfg. Co., Indian Orchard, Mass.

WANT INCREASED CLARIFIER EFFICIENCY?

Check REX *Verti-Flo!*

- Assures an effluent of maximum clarity.
- Requires detention periods of from ¼ to ½ of time required by conventional tank.
- Provides maximum capacity for any desired tank size.
- Operates efficiently at high overflow rates.
- Allows compact, economical grouping with other structures because of rectangular shape.





Rex Verti-Flo Clarifier delivers a highly clarified effluent with an extremely short detention period. This new, efficient unit consists of a series of adjustable weirs and baffles which divide a rectangular settling tank into a series of cells. Weirs are adjusted to regulate closely the flow distribution among the cells for maximum efficiency. Extremely long weir length is obtained with this unique principle. The combination of large weir length and low vertical velocities assures a clearer effluent . . . far greater capacity . . . minimum cost.

Rex Verti-Flo can be installed in existing tanks to increase capacity and improve performance. In new construction, use of this highly efficient unit can help reduce construction costs by holding required tank size to a minimum.

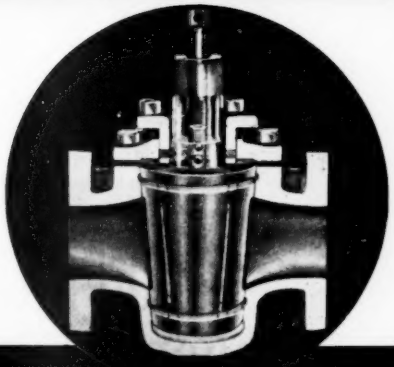
Rex Conveyor Sludge Collectors can be used with Verti-Flo to concentrate sludge at one end of the tank and to maintain a fluid sludge blanket where desired.

For all the facts, write Chain Belt Company, 1606 West Bruce Street, Milwaukee 4, Wis.

CHAIN BELT REX COMPANY — SANITATION EQUIPMENT

Nordstrom valves cost less in terms of service rendered

IN SEWAGE DISPOSAL PLANTS



SEALDPORT..... THE SYSTEM THAT LUBRICATES, SEALS AND JACKS THE PLUG

NORDCOSEAL..... TESTED VALVE LUBRICANTS, COMPOUNDED FOR SPECIFIC SERVICES

TAPERED PLUG..... INSURES PERMANENT, LEAK-PROOF SEATING AT ANY PRESSURE

GUARDED SEAT..... UNEXPOSED TO ABRASIVE OR CORROSIVE MATERIALS IN LINE

ROTARY ACTION..... SIMPLE QUARTER-TURN OPENS OR CLOSES VALVES

STREAMLINED..... SMOOTH-WALLED FLOW PASSAGES

Use only genuine Nordcoseal lubricants

NORDSTROM VALVE DIV.—*Rockwell Manufacturing Co.*
400 N. Lexington Ave., Pittsburgh 8, Pennsylvania

Atlanta, Boston, Chicago, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa . . . and leading Supply Houses

Export: Rockwell International Corp., 30 Rockefeller Plaza, New York 20

Nordstrom
LUBRICATED VALVES

KEEP UPKEEP DOWN

DON'T LET HIGH COSTS SABOTAGE YOUR SEWER BUDGET

It's true that material and labor costs are higher, but they need not undermine your sewer budget. A large portion of the total installed cost is in labor, and here is something you can do about *that!*

You can save up to 25 per cent or more of labor costs by specifying ARMCO Sewer Pipe. This is how it is done . . .

ARMCO Corrugated Metal Pipe is light in weight, easy to haul and handle using only ropes and plank skids. Long lengths mean fewer joints—less assembly—faster installation. No special foundations are required and no time is lost in curing. Unskilled labor quickly makes tight joints, using simple band couplers. On extra large sewers sturdy, prefabricated MULTI-PLATE sections are delivered to the site ready for speedy, low-cost installation.

You will also find other advantages in ARMCO Sewer Structures. Install them under railways and highways without worry of breakage or loading failures. There is a size and type for every purpose. ARMCO PAVED-INVERT Pipe combats erosion. ASBESTOS-BONDED Pipe provides all the durability you will ever need. Where headroom is limited ARMCO PIPE-ARCH saves time and labor.

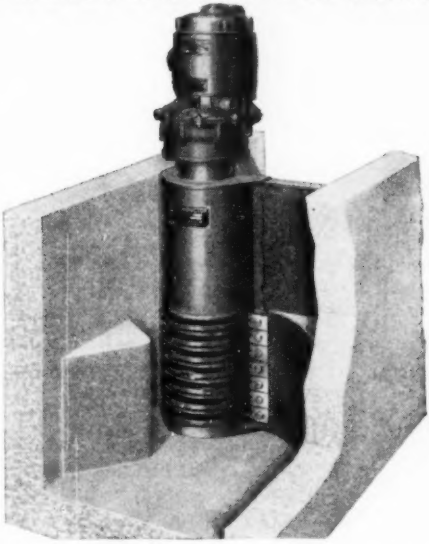
An ARMCO Engineer will be glad to demonstrate how you can save time and money on your specific problems. Ask him about ARMCO Sewer Structures before figuring that next job. Armco Drainage & Metal Products, Inc., 175 Curtis Street, Middletown, Ohio.

ARMCO

ARMCO SEWERAGE PRODUCTS

GRIDUCTOR®

STRAIGHT CHANNEL SEWAGE SCREENING AND CUTTING



SEND FOR..

Your copy of Bulletin No. 5100 . . an eight-page illustrated folder describing the GRIDUCTOR in complete detail with drawings, and charts of operation, parts, installation and capacities.

A *BETTER* Way to *Reduce Solids!*

GRIDUCTOR *Intercepts* and *Reduces* the larger solids in a normal sewage stream. Interception is by screen or grid action . . reduction by intermittant cutting without excessively increasing the dissolved organic content of the sewage. Other superior advantages are; 1. Easy *straight channel* installation, 2. Protection against fouling and clogging of treatment plant units, 3. Solids settle more readily in primary clarifier, 4. More gas production, 5. Coarse and fine screening actions are combined with cutting and shearing, 6. Little loss of head whether cutters are idle or operating, 7. Low operating cost, 8. Long life.

GRIDUCTORS are giving highly satisfactory service from coast-to-coast. A firm of well known designing engineers writes . . "He is obtaining excellent service from the Infilco Griductor. Hospital sewage presents a far more difficult problem because bandages, wrappings and larger quantities of all sorts of garbage are treated!" Get complete information now. Call or write our nearest field engineer or send for our Bulletin No. 5100.

INFILCO

* BETTER WATER CONDITIONING * AND WASTE TREATMENT SINCE 1894

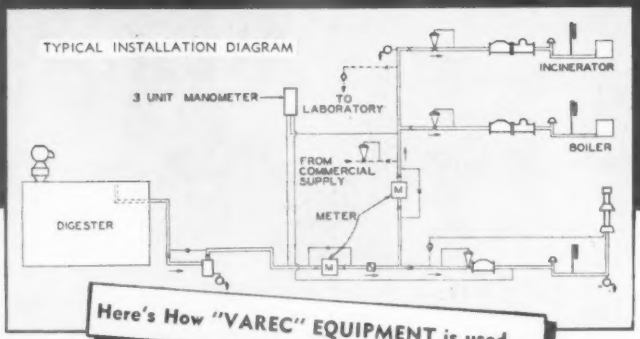
INFILCO INC.

GENERAL OFFICES: 925 WEST 25th PLACE • CHICAGO 16, ILLINOIS

SALES OFFICES IN TWENTY-SIX PRINCIPAL CITIES

WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

AUTOMATIC WASTE GAS BURNING
WITH
"VAREC" SEWAGE GAS CONTROL EQUIPMENT



Here's How "VAREC" EQUIPMENT is used....

"VAREC" Fig. 58C Pressure Relief and Vacuum Breaker Valve with Flame Arrester—*Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.*

"VAREC" Fig. 230, 232 or 233 Sediment Trap } *keeps lines drained and*
"VAREC" Fig. 245 or 248 Drip Trap } *free from moisture.*

"VAREC" Fig. 211 or 211A Check Valve—*controls direction of gas flow.*

"VAREC" Fig. 51A or 52A Flame Check—*prevents flashback from burner pilot light or laboratory burners.*

"VAREC" Fig. 440 Pressure Relief and Flame Trap Assembly—*permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.*

"VAREC" Fig. 187 or 387 Pressure Reducing Regulator—*controls pressure of gas going to utilization equipment.*

"VAREC" Fig. 450 Flame Trap Assembly—*prevents flame propagation in piping.*

"VAREC" Fig. 70 Explosion Relief Valve—*relieves sudden surges in pressure from explosion or momentary plant fluctuations.*

"VAREC" Fig. 215, 215A, 216 or 216A Manometer—*indicates system pressures.*

"VAREC" Fig. 236, 237 or 238 Waste Gas Burner—*efficiently burns all excess gas.*

Write for Catalog S-3

PROVED and APPROVED "Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY
COMPTON, CALIFORNIA, U.S.A.

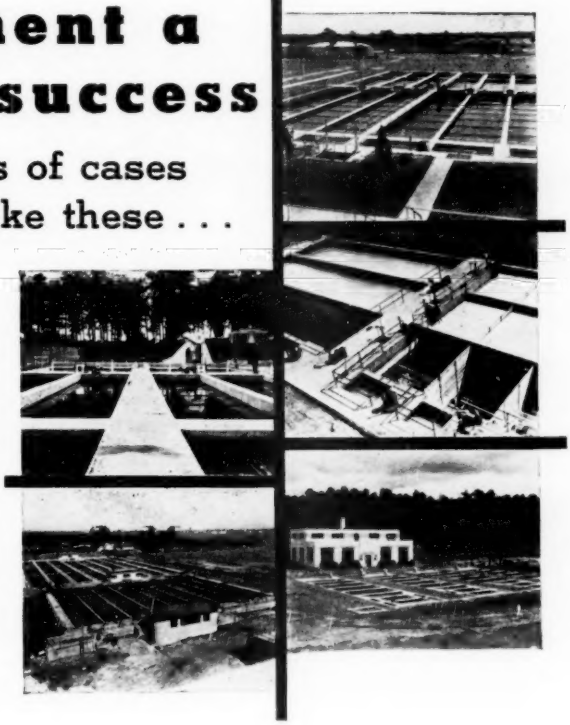
NEW YORK 30 CHURCH ST · PITTSBURGH 939 GULF BLDG · CHICAGO 122 SO MICHIGAN AVE
TULSA 409 TULOMA BLDG · HOUSTON 821A M & M BLDG

Available from Authorized Sewage Equipment Agents throughout U S and Canada

S-7

treatment a success

in hundreds of cases like these . . .



Five Jeffrey-equipped treatment plants are shown here. They include towns and cities serving populations ranging from 1500 to several million. Find out about Jeffrey Collectors, Bar Screens, FLOCTROLS, Grit Washers, Sludge Elevators, Scum Removers, Chemical Feeders, Screenings Grinders, etc.

When you really want to correct your ills you go to a specialist. That is just good sense. Many cities with growing pains have called in Jeffrey, M D (Mechanically-Designed) for equipment to treat water and sewage effectively. Jeffrey Sanitation Engineers are specialists. You can turn your problem over to them with full confidence for it's a TREAT TO GET GOOD TREATMENT.

JEFFREY ESTABLISHED 1877

SALES OFFICES IN PRINCIPAL CITIES

THE JEFFREY MANUFACTURING COMPANY 902 NORTH FOURTH STREET, COLUMBUS, OHIO

Vancouver, British Columbia builds new large-diameter sewer of *CONCRETE PIPE*

Sixty-inch concrete pipe was selected by the Greater Vancouver Joint Sewerage and Drainage Board for the Borden Trunk Sewer shown above. This combination storm and sanitary sewer line was installed by a regular crew of the Board.

Whether you plan a similar large-diameter storm and sanitary sewer or a smaller residential sewer you can be sure that concrete pipe will meet every requirement.

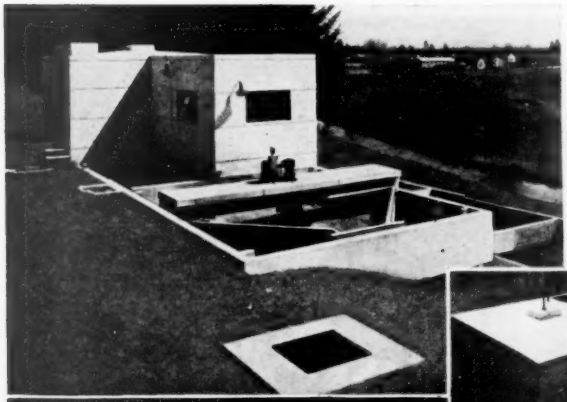
Concrete pipe's great strength enables it to resist severe impact and to sustain heavy overburdens. Its smooth interior walls provide maximum hydraulic capacity and resistance to abrasion. Concrete pipe's uniformly dense structure and joints that can be made watertight assure minimum infiltration and leakage.

The unusual durability of concrete pipe enables it to render many years of heavy-duty sewer service.

Dependable concrete pipe is moderate in first cost. It costs little or nothing to maintain. It has long life. In simple arithmetic, this adds up to low-annual-cost service -- the true measure of sewer line economy.

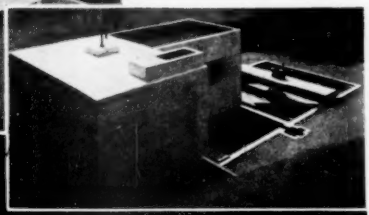
PORTLAND CEMENT ASSOCIATION

A national organization to improve and extend the uses of portland cement and concrete...through scientific research and engineering field work • 33 W. Grand Avenue Chicago 10, Illinois



No odors, no flies, this plant can be located near habitation.

Simple design using a single compact concrete unit minimizes construction cost.



Here's a

"PACKAGE" TREATMENT PLANT *for* modest budgets

FOR COMMUNITIES UP TO 3500 POPULATION • INDUSTRIAL PLANTS • INSTITUTIONS • AIRPORTS • HOUSING PROJECTS

Many small communities and outlying institutions, compelled to purify wastes but lacking ample supply of diluting water, have solved a critical problem by installing Yeomans "Package" Aerifier activated sludge plants.

HIGH EFFICIENCY AT LOW COST

Here indeed is a highly efficient means of purification, designed to fit the modest budget. In a single compact concrete unit of minimum dimensions you get aeration and final sedimentation, producing crystal-clear effluent at remarkably low over-all plant cost. Free from odors and flies, the plant can be put near habitation. Operation is simple, with supervision limited to routine check-up. All units are open for visual inspection. Of permanent concrete construction the plant will serve efficiently for many years.

THOROUGHLY ENGINEERED

Every installation of the Yeomans "Package" Aerifier includes final adjustment, initial tested operation, thorough training of operators and continued counsel from an organization with a 50-year reputation for sound engineering.

A Yeomans recommendation, based on a full statement of your needs and complete with construction cost estimates and application engineering, will be sent upon request.

YEOMANS BROTHERS COMPANY, 1411 NORTH DAYTON STREET, CHICAGO 22, ILLINOIS

For handling and treatment of domestic sewage and industrial waste, Yeomans manufactures: Yeomans Aero-Filter, high capacity trickling filter process • Yeomans "Package" Aerifier, activated sludge process • Rectangular and Circular Sludge Collectors • Digesters • Centrifugal and Pneumatic Sewage Ejectors • Scum, Grease and Sludge Pneumatic Ejectors Rotary Distributors • Plunger Sludge Pumps

YEOMANS

For abrasive ladings A.C.F. Lubricated Plug Valves with clear full circular ports* are ideal. Compact size is retained only through cylindrical plug design...straight-through flow with same shape and cross section as the pipe. Quick quarter turn to open or close...no exposed seats. For every reason A.C.F. Valves should be your first choice.

*Also offered with full area rectangular ports.

a.c.f. CYLINDRICAL FULL PIPE AREA LUBRICATED **PLUG VALVES**

Representatives in more than 50 principal cities

Ideal for sewage operations. Ask for catalog 4-SJ. American Car and Foundry Company, Valve Division, 30 Church St., New York 8, N. Y.

In Sewage Works Instrumentation!

Brown engineered instrumentation for sewage works gives you the most complete coverage of your indicating, recording or controlling requirements. You might call us "Headquarters" for your instrumentation needs . . . for Digesters, Dryers, Incinerators, Boilers, Mixing Basins, Elutriators, Sludge Lines, Room Heating, etc.

Whether you're planning a complete new plant or merely an addition, it's a safe bet that a Brown instrument can help!

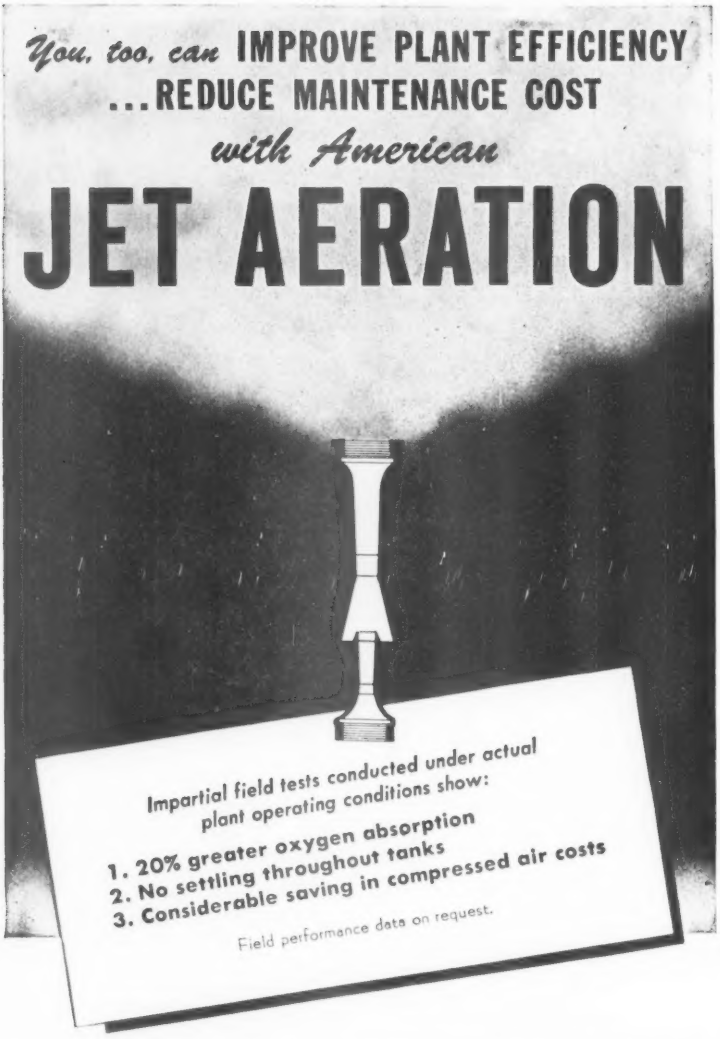
If you don't have a copy of catalog 7301, send for one today . . . it gives the complete story on Brown instrumentation for the treatment of sewage and industrial wastes.

MINNEAPOLIS-HONEYWELL REGULATOR CO.
BROWN INSTRUMENTS DIVISION
4518 Wayne Ave., Philadelphia 44, Pa.

Offices in principal cities of the United States, Canada and throughout the world

Honeywell *Advanced Instrumentation* FOR SEWAGE TREATMENT BROWN INSTRUMENTS

You, too, can **IMPROVE PLANT EFFICIENCY**
...REDUCE MAINTENANCE COST
with American
JET AERATION



Impartial field tests conducted under actual plant operating conditions show:

1. 20% greater oxygen absorption
2. No settling throughout tanks
3. Considerable saving in compressed air costs

Field performance data on request.

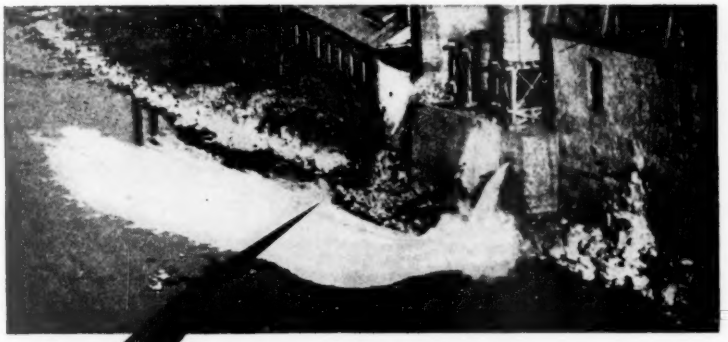
Our staff of Sanitary Engineers will cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

AMERICAN WELL WORKS

IN OUR 81ST YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago • New York • Cleveland • Cincinnati • Kansas City • Sales Representatives throughout the World



General Chemical "ALUM"

For Treatment of Industrial Wastes

Throughout the process industries, scores of concerns have found General Chemical Aluminum Sulfate an effective, economical means of solving their industrial waste treatment problems.

Laundries, paper mills, dairies, textile mills, canning plants, oil wells and packing houses across the nation report General Chemical "Alum" useful in purifying wastes; coagulating and settling suspended matter; reducing coloring matter, including many dyes.

Fifty years of working with the water industry on chemical methods of clarifying water has given General Chemical extensive experience in the treatment of sewage and waste waters. This broad knowledge may be of value to you as it has to so many others.

Assistance of the company's technical service specialists is available without obligation. For help on your industrial waste treatment problems, write or phone our nearest office today.

BASIC CHEMICALS FOR AMERICAN INDUSTRY

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport Buffalo • Charlotte • Chicago • Cleveland • Denver • Detroit • Houston Kansas City • Los Angeles • Minneapolis • New York • Philadelphia Pittsburgh • Portland (Ore.) • Providence • San Francisco • Seattle St. Louis • Wenatchee and Yakima (Wash.)
In Wisconsin: General Chemical Company Inc., Milwaukee, Wis.
In Canada: The Nichols Chemical Company, Limited
Montreal • Toronto • Vancouver

Sanitary mains of the pressure type call for a rugged pipe material and permanently tight joints. If the installation is planned for permanence the pipe must have ample safety-margins in beam-strength, compressive-strength and impact-resistance, and, above all, it must effectively resist corrosion. If the main is to be efficient and economical, the joints must be *infiltration-proof*. The one sure way to plan a pressure sewer meeting all these requirements is to specify cast iron pipe. For informative booklet "Cast Iron Pipe in Sewerage Systems," write to Cast Iron Pipe Research Association, Thomas F. Wolfe, Engineer, Peoples Gas Building, Chicago 3.

CAST IRON PIPE
SERVES FOR CENTURIES
LOOK FOR THIS MARK IT IDENTIFIES CAST IRON PIPE

SEWAGE WORKS JOURNAL

Official Bimonthly Publication — Federation of Sewage Works Associations

Volume XXI | JULY, 1949 | Number 4

Contents

Sewage Works

Effect of Certain Detergents on Sewage Treatment. By Willem Rudolfs, Raymond Manganelli, and Isaiah Gellman 605
Quantitative Relationships in the Activated Sludge Process. By L. S. Kraus 613
Discussion by Earnest Boyce 622
Factors Affecting the Efficiency of Activated Sludge Plants. By William E. Stanley 625
Discussion by Gail P. Edwards 640
The Oxygen Requirements of Activated Sludge Determined by Manometric Methods. By P. S. S. Dawson and S. H. Jenkins 643
Biology of Sewage Treatment. By James B. Lackey 659
Discussion by Gerard A. Rohlich 665

Industrial Wastes

Dairy Waste Disposal. By Edward F. Eldridge 668
Wastes from Chemical Manufacturing. By Raymond W. Hess 674
Discussion by Thomas J. Powers 683
A High Rate Trickling Filter Pilot Plant for Certain Chemical Wastes. By B. W. Dickerson 685
Waste Control in a Coke Plant. By K. N. Bundy and P. E. Jordan 694
Compressed Yeast Waste Treatment. V. Sludge Formation, Characteristics and Changes. By Willem Rudolfs and Eugene H. Trubnick 700

Stream Pollution

Legal Indices of Stream Pollution. By Don E. Bloodgood 711
Discussion by Robert N. Clark 716

The Operator's Corner

The Life You Save 719
Chlorine Cylinder Rupture at Ridgewood Sewage Treatment Plant. By John W. Hood 720
1948 Operators' Forum 722
Operating Problems from Tannery Wastes at Ballston Spa. By William Porter .. 738
Tips and Quips 743

Editorial

Trend Toward Preaeration 748

Proceedings of Member Associations

Arkansas Water and Sewage Conference 750
Oklahoma Water and Sewage Conference 750
Kansas Sewage Works Association 751
Member Association Meetings 752

Federation Affairs

Boston Convention Developments 753

Reviews and Abstracts 755

Book Review 762

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
Herbert P. Orland, *Assistant Editor* Dr. F. W. Mohlman, *Advisory Editor*
Kathleen E. Fox, *Editorial Assistant*

Copyright, 1949, by the Federation of Sewage Works Associations, Inc. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

in sewage treatment...

THERE'S A DORR UNIT *for practically*

EVERY STEP IN EVERY FLOWSHEET

● FOR PRELIMINARY TREATMENT

1. The Dorrco Bar Screen
* The Dorrco Fine Screen
2. The Dorrco Sulzer Disintegrator
3. The Dorr Detritor
* The Dorrco Vacuator

● FOR PRIMARY TREATMENT

* The Dorrco Flocculator
4. The Dorr Clarifier
or
* The Dorrco Monorake

● FOR SECONDARY TREATMENT

5. The Dorr Clarifier
or
* The Dorrco Monorake
6. The Dorrco Distributor

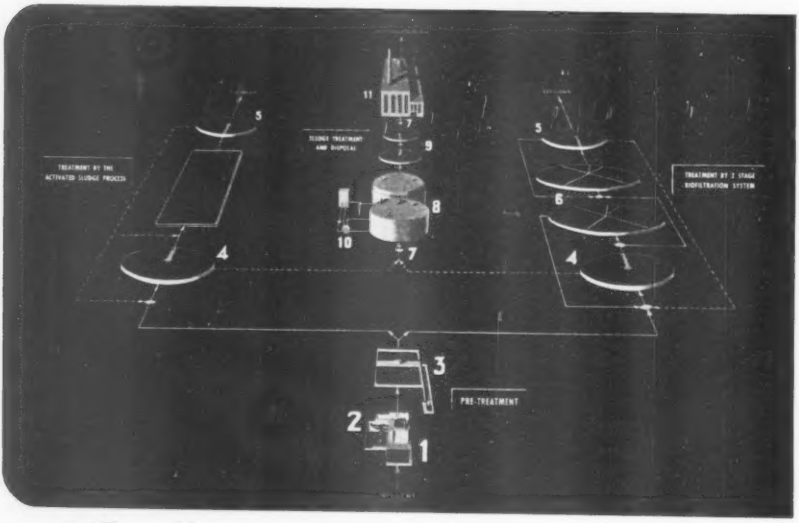
● FOR SLUDGE TREATMENT AND DISPOSAL

7. The Dorrco Sludge Pump
8. The Dorr Multidigestion System
* The Dorr Digester
9. The Dorr Thickener
10. The Spiral Heat Exchanger
11. The C-E Raymond System (Sludge drying-incineration)

● FOR COMBINATION TREATMENT

* The Dorr Duo-Clarifier (primary and secondary clarification)
* The Dorrco Duo-Filter (primary and secondary filtration)
* The Dorrco Clariflocculator (flocculation and clarification)
* The Dorr Clarigester (clarification and digestion)
* The Currie Claractor (aeration and clarification)
* The Dorrco Vacuator (for grit, scum and solids removal)

* Alternative or combination units not shown on composite drawing.



If you do not already have information on all the Dorr units shown in the composite flowsheet above, write for your copy of "Dorr Equipment and Methods" . . . 12 pages of photos and descriptions covering every unit in the Dorr line.

DORRCO

THE DORR COMPANY, ENGINEERS
570 LEXINGTON AVE., NEW YORK 22, N. Y.
ATLANTA • TORONTO • CHICAGO
DENVER • LOS ANGELES
RESEARCH AND TESTING LABORATORIES
WESTPORT, CONN.
SUGAR PROCESSING
PETREE & DORR DIVISION, NEW YORK 22, N. Y.
ASSOCIATES AND REPRESENTATIVES
Dorr Technical Services and Equipment Are Also Available Through Associated Companies and Representatives in the Principal Cities of the World. Names and Addresses on Request.

RESEARCH ENGINEERING **DORR** EQUIPMENT

Sewage Works

EFFECT OF CERTAIN DETERGENTS ON SEWAGE TREATMENT *

By Willem Rudolfs, Raymond Manganelli, and Isaiah Gellman

During the last several years the use of synthetic detergents in industry and homes has greatly increased. This increased use undoubtedly was stimulated by the scarcity of soap during the war years. Whereas before the war the quantities of surface active agents produced were relatively small (a few million pounds), since the war production has increased greatly (Table I). For instance, in 1941 the production of surface active agents in the United States was about 28,000,000 lb.; in 1945, (the latest figures available) the production amounted to about 185,000,000 lb; unofficial estimates for 1948 indicated 800,000,000 lb., or 20 per cent of soap production. Soap production tended to decline (1).

TABLE I. Production of Soaps and Surface Active Agents

Year	Soaps (lb.)	Surface Active Agents	
		(lb.)	(%)
1941	3,147,000,000	27,960,000	0.9
1942	2,929,000,000	31,193,000	1.1
1943	2,826,000,000	59,576,000	2.1
1944	3,291,000,000	152,636,000	4.7
1945	2,872,131,000	184,442,000	6.5

There is on the market a great variety of synthetic detergents, which, in general, may be placed into four groups: (1) cationic compounds, such as quarternary ammonium compounds; (2) anionic compounds, such as fatty alcohol sulfates (Dreft) and sodium alkyl aryl sulfonate (Nacconol N. R.); (3) nonionic materials, such as sulfonated mineral oils; and (4) mixtures containing other ingredients. The quarternary ammonium compounds are generally used for sanitizing eating utensils; materials with trade names, such as Vel, Dreft, Swerl, Co-op, etc., are packaged for household use; and Nacconol N.R. has been used to demonstrate its value for oil and grease removal from city streets. (Swerl is the trade name for packaged material sold in bulk as Nacconol.)

Glassman (2) has brought together a large amount of pertinent information concerning surface active agents and their application in bacteriology. A presentation of data, and a theoretical discussion of the effect of detergents on biological systems and of theories of action, is out of place in this paper, which is confined to some of the practical aspects pertaining to the effect of detergents on various phases of sewage treatment. This paper is of a preliminary nature and results presented are illustrations rather than complete results obtained. Results on other types of detergents, together with data obtained on specific problems, where larger amounts of grease, soap, and oils, and consequently greater quantities of detergents, are involved, as well as the effect of coagulants on detergents and the effect of detergents

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Department of Sanitation, Rutgers University.

on coagulants, will be published in following contributions.

The compounds used for experimental purposes were bought in packaged form, ready for household use, except Nacconnol N.R., which was obtained from the manufacturer. To estimate the possible effect of the surface active agents on the sewage characteristics and various treatment devices, the quantities of detergents added were limited to those which may be expected in domestic sewage; namely, from 10 to 100 p.p.m.

Effect on Strength of Sewage

Two of the characteristics of the detergents used—namely, pH and B.O.D. —are shown in Table II, together with

TABLE II.—B.O.D. of Certain Detergents and Soaps

Name	pH*	B.O.D. (p.p.m.)
Detergents:		
Co-op	8.3	0
Swerl	6.3	0
Dreft	6.6	491,000
Vel	6.3	266,000
Nacconol N.R.	6.3	0
Soaps:		
Ivory Snow	9.6	1,410,000
Lux Flakes	9.5	1,470,000
Super Suds	9.8	975,000

* of 0.1% solution.

the B.O.D. of some soaps commonly used for household purposes. The results show that some of the detergents are slightly acid and others slightly alkaline. Some of the detergents exhibit no B.O.D., whereas others may have values as high as 500,000 p.p.m. These values are substantially lower than those for the widely used household soaps. There is no doubt that some of the detergents add to the B.O.D. load of sewage, but on the assumption that the detergents would replace the soap and the quantities used were similar to the amounts of soap used, the strength of the sewage would decrease. Experience has shown that the amounts of soap present in domestic sewage vary from 20 to 50 p.p.m., and if it is assumed that the soap was replaced by detergents, the actual B.O.D. of the sewage would decrease by 15 to 40 p.p.m., depending on the detergent used. In general, therefore, the use of detergents will not increase the strength of the sewage.

Effect on Settling

One of the functions of synthetic detergents is to lower the surface tension of liquids. Theoretically, decreased surface tension should facilitate settling of suspended matter. To determine the effect of small quantities of several brands of detergents on the rate of settling of suspended material, amounts varying from 10 to 100 p.p.m. were added to samples of average and strong sewage. The removal of suspended solids was determined at frequent intervals of quiescent settling. The results obtained showed that Vel and Co-op, although greatly differing in pH and B.O.D., had the least effect on the settling rates. Nacconol N.R. in amounts of more than 30 p.p.m. caused a slight retardation, whereas Dreft, being nearly neutral but with a relatively high B.O.D., had a consistent effect on the settling rate (Figure 1).

With increasing concentrations of detergents, more suspended solids remained in the effluent. The suspended solids remaining in the effluent of a strong sewage after 60 min. quiescent settling gradually increased with increasing amounts of detergent, varying from a few per cent with the lowest concentration of detergent to about 20 per cent with the highest amount of detergent added.

Effect on Sludge Volume

A series of experiments with average and strong raw sewages showed that

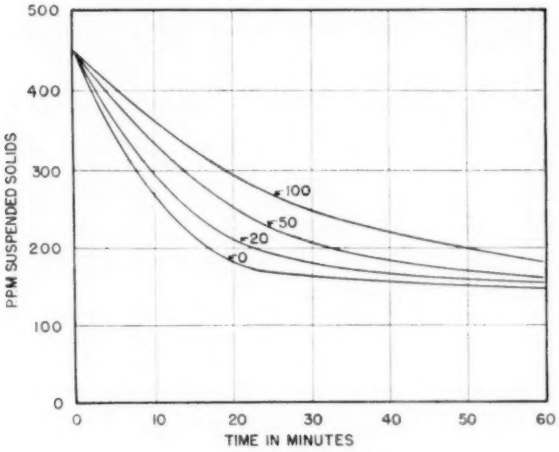


FIGURE 1.—Effect of increasing quantities of detergent (Dreft) on the rate of settling.

the detergents have no appreciable effect on the volume of sludge produced, except Dreft which, despite lower removal of suspended solids, produced a persistently larger volume of sludge (varying from 7 to 18 per cent).

Effect on Grease Removal

"Grease" in sewage is mostly derived from soaps, which react with the mineral constituents in water (calcium, magnesium, iron), are precipitated, and are removed from the water. Detergents do not form precipitates and prevent the precipitation of soaps. To determine the effect of detergents on grease removal by settling, a series of experiments were made with average and strong samples, using various quantities and different brands of detergents. Results of four sets of experiments (Table III) show that Vel, Dreft, and Nacconol N.R. addition resulted in increasing amounts of grease in the effluent. Small quantities of the detergent Co-op seemed to have no appreciable effect, whereas larger quantities appeared to aid grease removal. Attention is drawn to the fact that the detergent Co-op is alkaline in nature, whereas the other detergents are very slightly acid.

Effect on B.O.D. Removal

Soaps have a very high B.O.D. Because some detergents added to sewage cause a decrease in removal of grease on sedimentation of sewage, it might be expected that the B.O.D. of the settled sewage would increase. Experiments made with different sewages to which varying quantities of several brands of detergents were added showed that with strong sewages the B.O.D. generally increased the effluent.

TABLE III. Effect of Certain Detergents on Grease Removal by Settling

Quantity of Detergent (p.p.m.)	Grease Removal (p.p.m.)			
	Vel	Dreft	Nacconol	Co-op
0	30.7	73.0	28.5	90.3
10	30.0	81.2	36.3	94.0
30	34.8	83.6	39.7	72.2
100	42.6	92.2	54.2	75.0

TABLE IV.—Effect of Certain Detergents on Percentage B.O.D. Reduction after Settling Strong Sewages

Quantity of Detergent (p.p.m.)	B.O.D. Reduction (%)			
	Vel	Dreft	Nacconol	Co-op
0	64.8	56.5	62.5	46.5
10	62.0	54.0	63.5	49.5
20	61.2	56.5	59.7	46.6
30	63.0	55.0	58.5	57.5
50	62.5	55.6	55.5	50.5
100	56.0	55.5	50.5	50.0

but the precentages of B.O.D. removal were not materially affected, except with Nacconol N.R., which has a measurable effect when added in higher concentrations. A summary of the results obtained is shown in Table IV.

Toxicity of Detergents Used

Soaps have a very high B.O.D., but quantities up to 1,000 p.p.m. cause no retardation of oxidation as measured by the direct and dilution methods of B.O.D. determination. Experiments with various synthetic detergents showed that Vel and Dreft were readily oxidized in concentrations of 1,000 p.p.m. Detergents present in sewage in quantities approximating concentrations of soaps do not interfere with sewage oxidation. The detergent Nacconol (Swerl) may cause some effect on the rate of oxidation when present in quantities of 100 p.p.m. or more, but in the range of concentrations in which soaps are found there is little, if any, retardation of biochemical activity.

Effect on Activated Sludge

Experiments were made with activated sludge (conducted by the fill and draw method) by adding various quantities of detergents with each dose of sewage. The object of the study was to obtain indications concerning the effect of detergents on the volume of sludge produced, on the suspended solids in the mixed liquor, on the sludge index, on purification (as shown by suspended solids and B.O.D. in the effluent), and on foaming. Well settling and also bulking activated sludges were used, both with low and average solids concentrations in the mixed liquors. Brief summaries of the results obtained are given in Tables V and VI to illustrate the conclusions reached.

With increasing quantities of Nacconol N.R. the sludge index gradually decreased, whereas the suspended solids and B.O.D. in the effluent increased. A considerable amount of foaming occurred, which increased with increasing amounts of the detergent added. The floc, which was carried upward by the foam, was deposited in aggregates and also lost with the foam, resulting in a constant decrease of the suspended solids in the mixed liquor.

Vel, used in conjunction with an

TABLE V.—Effect of Nacconol N.R. on Activated Sludge, Using Low Mixed Liquor Concentrations

Quantity of Detergent (p.p.m.)	Sludge Volume (%)		Susp. Solids in Mixed Liquor (p.p.m.)		Sludge Index		Effluent			
							Susp. Solids (p.p.m.)		B.O.D. (p.p.m.)	
	Second dosage	Eighth dosage	Second dosage	Eighth dosage	Second dosage	Eighth dosage	Second dosage	Eighth dosage	Second dosage	Eighth dosage
0	11.4	8.0	1048	640	109	125	29.5	11.0	43.0	14.4
10	11.4	5.0	1112	456	102	109	23.5	8.5	27.3	19.7
25	8.9	3.9	988	296	90	131	22.5	13.5	32.7	30.7
50	6.7	2.0	852	220	78	91	18.5	20.0	41.5	36.7
100	6.7	2.2	816	276	82	80	23.0	23.0	44.3	44.7

TABLE VI.—Effect of Vel, Dreft, and Co-op on "Normal" and Bulking Sludge, Using Average Concentrations of Suspended Solids in Mixed Liquor (Eighth Dose)

Detergent (p.p.m.)	Sludge Vol. (%)	Susp. Solids Mixed Liquor (p.p.m.)	Sludge Index	Effluent	
				Susp. Solids (p.p.m.)	B.O.D. (p.p.m.)
Vel—					
0	18.2	1824	99	10.0	21.6
10	19.5	1612	121	7.2	16.8
25	18.7	1636	114	7.6	20.4
50	20.2	1728	116	12.4	15.9
100	18.7	1752	106	7.6	13.2
Dreft—					
0	28.8	1412	204	22.0	31.2
10	25.9	1220	212	21.5	29.1
25	28.0	1404	179	19.5	45.6
50	15.1	1152	140	19.5	38.5
100	10.5	1008	104	21.0	38.7
Co-op					
0	28.8	1412	204	22.0	31.2
10	15.7	1140	138	22.5	43.2
25	9.7	868	126	24.0	36.9
50	7.7	972	79	25.0	50.4
100	6.4	696	82	51.5	63.6

average solids concentration in the mixed liquor, had no measurable effect on the sludge index or degree of purification. The detergent caused some foaming, particularly with concentrations of 50 and 100 p.p.m., but the foaming was much less than that caused by Nacconol in concentrations of 10 and 25 p.p.m.

Dreft or Nacconol added to bulking sludge caused a definite decrease in the sludge index had no measurable effect on the suspended solids in the effluent, but showed a tendency to cause an increase in the B.O.D. The detergents again caused aggregation of the floc and considerable foaming.

Co-op, added to bulking sludge, caused a considerable decrease in the sludge index. Separation between sludge and liquid was enhanced and clear cut. The suspended solids and B.O.D. in the effluent increased with increasing concentrations of the detergent. The detergent caused considerable foaming and aggregation of the floc. The turbidity of the effluent gradually increased, becoming greater with increasing amounts of detergent.

Effect on Digestion

A series of fresh solids-ripe sludge mixtures was prepared, using 2 parts of fresh solids to 1 part of ripe sludge on a volatile matter basis. The detergents Vel, Dreft, and Nacconol N.R. were added in concentrations of 10, 25, 50, and 100 p.p.m. to the various mixtures, which were incubated at 20° C. for 31 days.

The results obtained show that the detergents had no material effect on volatile matter destruction, grease reduction, or gas production. A brief summary of the results obtained with 100 p.p.m. detergent illustrates these conclusions (Table VII). It appeared, however, that the rate of digestion might be somewhat more rapid. This is illustrated by Figure 2, which shows that the peak of daily gas production was reached two days earlier with 100 p.p.m. Nacconol than without detergent. The curves for mixtures with lower quantities of detergent indicate

TABLE VII.—Effect of Detergents on Digestion

Sludge Condition	pH	Total Solids (%)	Vol. Solids (%)	Grease (%)	Grease Red. (%)	Gas/gm. Vol. Solids (c.c.)
Initial	6.7	7.3	48.2	14.7	—	—
Digested, no detergent	7.2	6.5	41.2	5.8	60.5	503
Vel added	7.3	6.5	42.2	5.9	59.8	501
Dreft added	7.3	6.3	42.5	5.8	60.5	504
Nacconol added	7.3	6.5	43.0	6.1	58.5	486

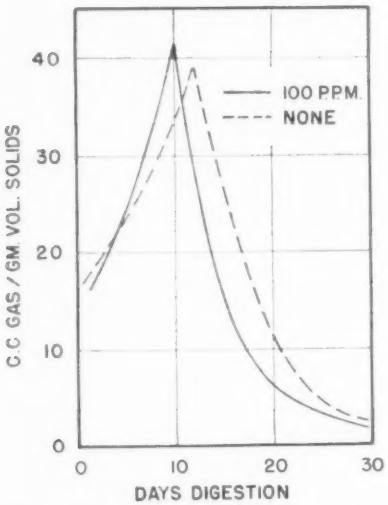


FIGURE 2.—Effect of detergent (Nacconol) on the rate of gas production.

decreasing effects with decreasing amounts.

Discussion

Scarcity of soap and effective advertising have probably aided the production and sale of detergents for industrial and domestic use during the last several years. Although the production of 185,000,000 lb. seems large, it is only 6.5 per cent of the total soap production. The question of the effect of detergents on sewage treatment is not of immediate general practical importance, but may be important locally where larger quantities of laundry wastes are received. Sewage treatment plants which handle industrial wastes containing larger quantities of soap may notice the effect when detergents replace soap. In general, replacement of soap by detergents will reduce the strength of sewage.

The effect of detergents on sewage treatment plants and various units is not uniform, some detergents having a greater effect than others. Certain detergents have a measurable effect on settling devices, resulting in poorer effluents. The increased suspended solids, but particularly increased B.O.D. in the effluent, may be important because a greater load is placed on secondary treatment devices.

Detergents will increase the amounts of colloidal suspensions. Observations show that 100 p.p.m. soap added to natural waters of various degrees of hardness is partly precipitated and removed on settling. The harder the water, the lower the B.O.D. caused by soap. Moreover, the percentage B.O.D. reduction after settling is much higher with harder waters. This is indicated by the following figures:

Hardness, p.p.m.	44	168	1250
B.O.D. before settling, p.p.m.	170	125	119
B.O.D., 1 hr. settling, p.p.m.	153	79	67
B.O.D. reduction, %	10	36.8	43.7

Addition of soap to water in conjunction with increasing amounts of detergents results in increased amounts of dispersed solids and higher B.O.D. of the effluent after settling. When the detergent has a B.O.D., the B.O.D. of the mixture, as well as the B.O.D. of the effluent after settling, increases as indicated by the following figures for soft water:

Detergent		B.O.D. Before Settling (p.p.m.)	B.O.D. After Settling (p.p.m.)	B.O.D. Reduction %
Nacconol,	25 p.p.m.	163	128	21.5
	50 p.p.m.	161	137	15.0
	100 p.p.m.	165	143	13.3
Dreft,	25 p.p.m.	167	149	10.8
	50 p.p.m.	195	173	11.8
	100 p.p.m.	220	193	12.2

Inasmuch as detergents are stable in hard waters, substitution of detergents for soap may appeal to users of hard water supplies, but may also cause increasing difficulties for the sewage plant operator. In hard water the detergents have a similar effect to that in soft waters, but less marked, unless sufficient detergent is available to

soften the water. This is indicated by the following relative B.O.D. figures obtained by adding about 100 p.p.m. soap and increasing quantities of detergent (Dreft):

Hardness (p.p.m.) 44			168			1250		
Before Settling (p.p.m.)	After Settling (p.p.m.)	Red. (%)	Before Settling (p.p.m.)	After Settling (p.p.m.)	Red. (%)	Before Settling (p.p.m.)	After Settling (p.p.m.)	Red. (%)
117	69	41.0	124	83	33.0	119	41	65.5
138	85	38.5	148	97	34.5	146	50	65.5
147	109	35.8	152	112	26.2	185	76	59.0

Although the B.O.D. of the effluent increases with increasing quantities of detergent in very hard water, the actual B.O.D. of the effluent is less than in soft water, unless the amounts of detergents are large enough to take care of the salts in solution.

There is no evidence that detergents present in quantities equal to the amounts of "grease" in domestic sewage are toxic to either aerobic or anaerobic biological processes. Replacement of soaps by detergents would not affect directly the biological activities in trickling filters, activated sludge or sludge digestion, but it would have an indirect effect on the operation and purification results. The principal effect to be expected on trickling filters is the increase in grease and finely divided substances in the effluent from settling devices, causing an increased load on the filters. A possible decrease in the degree of purification, especially from filters approaching their maximum loading capacity or from those already overloaded, is apparent.

The effect on the operation of the activated sludge process is threefold, namely: foaming, floc agglomeration, and carry over of suspended material. Some of the detergents cause more foam than others. Estimates of the amount of foam formed with 100 p.p.m. detergent added varied from a few inches to four or more feet, depending on the type of detergent. Smaller quantities of detergents produce proportionally less foam. Agglomeration of activated sludge floc results in more or less leathery pieces of floc attaching themselves to side walls, or settling rapidly because of their increased specific gravity, requiring more turbulence or more air to keep them in suspension, and conceivably may reduce the degree of purification. The foam formed is rather tough and contains a considerable amount of finely divided suspended solids. A portion of the foam, containing the suspended solids, remains on the surface of the settling tank and passes over the settling tank weir, impairing the effluent. The continuous carry-over may even affect the solids concentration in the mixed liquor and the rate of purification.

Some detergents decrease the quantity of (dry) solids retained in settling tanks and allow more grease to remain in the effluent. Although the detergents, as such, may not have a great effect on the rate of digestion of solids, the decrease in sludge quantity, particularly the decrease in grease retained by settling, results in smaller quantities of gas produced. As soap and greases present in sludge are the principal sources of the gas produced, the replacement of soaps by detergents, together with the effect of detergents on the amounts of grease retained,, may be serious at places where all gas is utilized for heat and power.

Summary

The types and quantities of detergents produced in the United States

have increased rapidly but still represent only a comparatively small percentage of the total soap production. In general, replacement of soap by detergents will reduce the strength of sewage. The effect of detergents on sewage plant units is not uniform, some detergents having a greater effect than others. Settling devices may be affected, producing a poorer effluent. Increased B.O.D. in the effluent from settling tanks may affect secondary treatment devices. The replacement of soaps by detergents may have the greatest effect in areas with soft water supplies, but may also cause considerable difficulty in hard water regions. The detergents tested are not toxic to biological activities, but have an indirect effect on sewage treatment plant operation. The principal effects appear to be: (1) decreased efficiency of settling tanks, with consequent increased load on trickling filters; (2) foaming, floc agglomeration, and carry-over in activated sludge units; and (3) reduction in gas production from sludge digestion.

References

1. U. S. Tariff Commission, "Synthetic Organic Chemicals, U. S. Production and Sales," Reports Nos. 148, 153, 155, 157 (1940, 1941, 1943, 1944, 1945).

2. H. N. Glassman, "Surface Active Agents and Their Application in Bacteriology." *Bact. Reviews*, **12**, 105–172 (1948).

GREASE INTERCEPTOR STANDARDS AVAILABLE

The "Testing and Rating Procedure for Grease Interceptors, Plumbing and Drainage Institute Standard, PDI–G101" will soon be available for distribution, according to a release of the Institute.

The basic testing procedure is designed to simulate an actual plumbing installation in which grease interceptors are subjected to severe operational conditions. To obtain certification the interceptor must have maintained an average efficiency of 90 per cent or more and an incremental efficiency of 80 per cent or more while retaining not less than 2¼ lb. of grease for each 1 g.p.m. flow rate. Included with the testing procedure is a table showing the certification standard flow rates and grease retention capacity ratings for grease interceptors and the recommended maximum capacity of fixtures to be connected to interceptors of various sizes.

The testing facilities of the United States Testing Co., Hoboken, N. J., are available to all manufacturers of grease intercepting equipment, and test certificates are issued by that laboratory for all interceptors meeting the requirements of Test Standard PDI–G101. Interceptors manufactured by members of the Plumbing and Drainage Institute and which have received certification will be distinguishable by the Institute's "Seal of Certification," affixed to the interceptors and showing the certified flow rate and grease retention capacity.

Requests for "Testing and Rating Procedure, PDI–G101" addressed to the Executive Offices of the Plumbing and Drainage Institute, 18925 Grand River Avenue, Detroit 23, Michigan, will be answered as soon as copies are available.

QUANTITATIVE RELATIONSHIPS IN THE ACTIVATED SLUDGE PROCESS *

By L. S. Kraus

Chemist, Greater Peoria Sanitary District, Peoria, Ill.

The early development of the activated sludge process, as well as the subsequent installation and operation of large plants, indicated that certain parameters were satisfactory for the successful operation of the process. As more and smaller plants were installed and greater experience was obtained it became apparent that difficulties were encountered because of limited facilities for handling sludges in various parts of the process. These difficulties were largely caused by the inability of the activated sludge to settle to the suspended solids concentrations anticipated in the plant design, and it became common practice to refer to this phenomenon as "bulking" of the activated sludge. Thus, bulking was related to the pumping capacities incorporated in a given plant and was looked on as an abnormal phenomenon. It is the intent of this paper to deal with varying sludge settleability, or density, as a variable, and to develop those parameters necessary to meet the requirements of this varying situation.

Causes of Bulking

The purification of sewage and industrial wastes by the activated sludge process is effected by a continuously varying mixed culture of microorganisms. The wastes being purified contain continuously changing mixtures of organic and inorganic compounds in varying concentrations. As the activated sludge becomes acclimated to certain organic compounds, the rate of removal of these materials increases. When the organic content of the sewage changes, the organisms must reacclimate themselves to the new nutrient materials. Thus, activated sludge may be thought of as a continuously changing biological medium in which different groups of organisms are increasing and decreasing in activity due to the varying nutrients in the wastes being purified and to varying environmental conditions.

The causes of bulking, or high sludge volume index, activated sludge are not specifically known, but have been considered to be brought about by the synthesis of insoluble organic compounds in the form of microorganisms and products produced by the effect of organisms on the dissolved, colloidal, and dispersed materials in the wastes treated. These insoluble substances are very low in density and compactibility and, being incorporated in the activated sludge, decrease the latter's settleability.

Ruchhoft *et al.* (1) in studies of the activated sludge process has indicated that two gross phenomena—oxidation and adsorption and synthesis—are proceeding simultaneously. When adsorption and synthesis predominate, the sludge increases in sludge index. The factors that influence the rate of adsorption and synthesis are considered to be both environmental (such as aeration liquor dissolved oxygen and carbohydrate content) and biological (in that the presence of the filamentous bacteria, *sphaerotilus natans*, is usually present in large quantities in bulking activated sludge). Although the causes of bulking are many and apparently complex, its effect can be measured by the sludge volume index. If the sludge volume index is treated as a variable

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations; Detroit, Mich.; Oct. 18–21, 1948.

which is the summation of many variables, the situation becomes sufficiently simple to resolve mathematically. In this approach, the following units and symbols are used:

Definition	Symbol
Sludge volume index	I
Initial	I_0
Of activated sludge formed	I_s
Rate of flow:	
Sewage (m.g./hr.)	S
Primary settling tank sludge (1000 gal./hr.)	P
Digester liquor (1000 gal./hr.)	L
Waste digested sludge (1000 gal./hr.)	D
Return activated sludge (m.g./hr.)	R
Waste activated sludge (m.g./hr.)	W
Suspended solids concentration:	
Sewage (p.p.m.)	s
Primary settling tank sludge (%)	p
Digester liquor (%)	m
Waste digested sludge (%)	d
Return activated sludge (p.p.m.)	r
Aeration liquor (p.p.m.)	a
Of activated sludge formed (p.p.m.)	b
Ratio of return activated sludge rate of flow to sewage rate of flow	v
Volume of aeration tanks (million cu.ft.)	Z
Suspended solids in activated sludge system (lb.)	A
Rate of suspended solids formed in activated sludge system (lb./hr.)	B
Rate of fresh solids removed in primary settling tanks (lb./hr.)	F
Time (hr.)	t

Sludge Volume Index—Time Relationship with Constant Solids in System

In developing the equations representing the rate of change of sludge volume index, two situations are considered: one, of constant activated sludge solids in the system; the other, of constant settled sludge volume in the system.

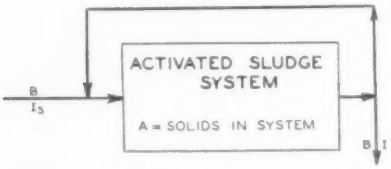


FIGURE 1.—Relationship between sludge volume index, I, with time, for activated sludge system in which the weight of activated sludge is kept constant.

At constant activated sludge solids, the following derivation applies. The differential equation states that the rate of change of sludge volume in the system, if it were to be suddenly settled ($A\,I$), is equal to the rate of activated sludge formed, B, times the difference of the sludge volume indexes of the sludge formed, I_s, and the sludge wasted, I. This is shown diagrammatically in Figure 1, and is expressed as follows:

$$\frac{d(A\,I)}{dt} = B(I_s - I)$$

or

$$\frac{dI}{I_s - I} = \frac{B}{A}\,dt$$

Integrating and simplifying,

$$I_s - I = C_2 e^{-\frac{B}{A}t} \quad \ldots\ldots (1)$$

When $t = 0$, $I = I_0$. Substituting these values in Eq. 1 gives

$$I_s - I_0 = C_2$$

Substituting for C_2 in Eq. 1 and simplifying,

$$I = I_s - (I_s - I_0)e^{-\frac{B}{A}t} \quad \ldots\ldots (2)$$

In order better to understand this expression, which establishes the sludge volume index as an exponential function of time, it is possible to assume values for I_s, I_0, B, and A, and to plot the curve of I for various values of t. This has been done in Figure 2 with the assumptions that $I_s = 500$, $I_0 = 100$, $B = 8.34\,S\,b$, $S = 1$, $b = 150$, and $A = 62.5\,Z\,a$. The value of Z is determined for a 6-hr. retention period with a return sludge of 25 per cent. This is equivalent to a 7.5-hr. retention period on the basis of sewage flow only. Thus, the value of Z used is 1 million cu. ft.

It is obvious from Figure 2 that the rate of change of the sludge volume index increases as the suspended solids in the aeration tanks decrease. It is

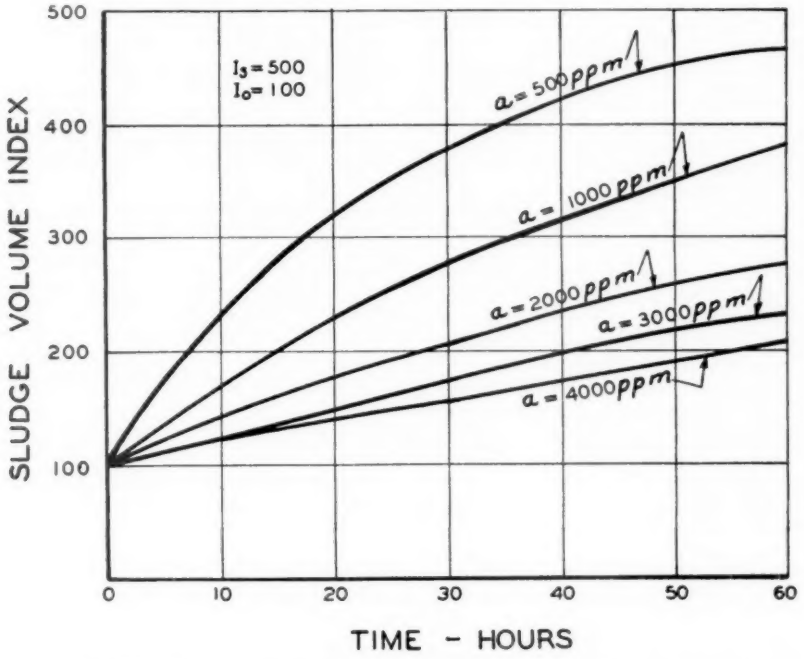


FIGURE 2.—Effect of high and low aeration liquor suspended solids on the rate of change of sludge volume index.

assumed that the sludge in the final settling tanks and the volume of waste digested sludge are sufficiently small to be omitted from the values of A and S. In this situation, the aeration tank suspended solids are held constant, and the rates of flow of return sludge and waste activated sludge are varied to compensate for the varying density of the activated sludge.

Return Sludge and Varying Sludge Density

In order to determine the value of the return sludge required at any time, it is necessary to establish a relationship between the suspended solids concentration of the return sludge from the final settling tanks and the sludge volume index. It is assumed that the return sludge concentration is an inverse function of the sludge index as follows:

$$r = \frac{10^6 K'}{I} \quad \ldots\ldots\ldots\ldots (3)$$

The value of the constant K' must be assumed, because to a large degree it is a function of the retention period and design of the final settling tanks. Bloodgood (2) has indicated in his studies that the value of K' should be 1. This means that the concentration of suspended solids in the return sludge should be equal to that obtained in the sludge after 30-min. settling of aeration liquor in a liter graduate. Experience has indicated that the value of K' can be as high as 1.2 for values of I less than 100. If operations are carried out to keep $K' = 1$, a reasonable factor of safety will be maintained for most values of I encountered in plant prac-

FIGURE 3.—Relationship between aeration liquor suspended solids, ratio of return sludge rate of flow to sewage rate of flow, and sludge volume index.

tice. In this paper the value of $K' = 1$ will be assumed in the equations derived; however, in application of the equations to a particular plant the value of K' most suitable to the particular situation may be used.

The solids balance in the final settling tanks (Figure 3) may be considered as a means of establishing the relationship between the aeration liquor suspended solids, a, the ratio, r, of the rate of flow of return sludge from the final settling tanks, R, to the rate of sewage flow, S, and the sludge volume index, I. Thus,

$$(S + R)\, a = R\, r$$

By substituting Eq. 3 in this expression and simplifying,

$$a = \frac{10^6 K'}{I} \frac{(R)}{(S + R)}$$

However,

$$\frac{R}{S} = r$$

so that

$$a = \frac{10^6 K'}{I} \frac{(r)}{(1 + r)}$$

and when $K' = 1$,

$$a = \frac{10^6}{I} \frac{r}{(1 + r)} \quad \ldots\ldots\ldots (4)$$

Thus is established an expression that relates the factors desired and makes it

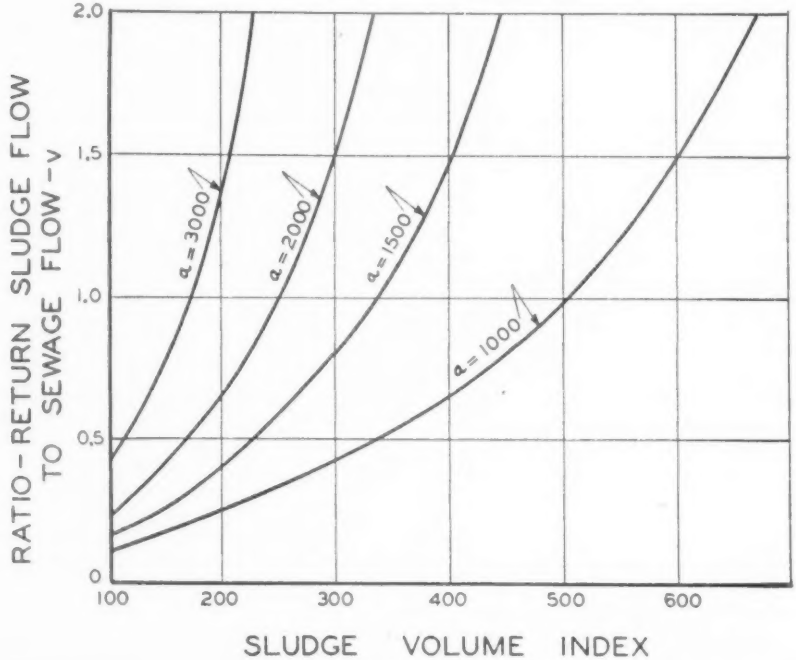


FIGURE 4.—Relationship between the return sludge ratio and sludge volume index for various levels of aeration liquor suspended solids concentration.

possible to plot the curves shown in Figure 4.

An inspection of Figure 2 makes it apparent that it is most desirable to maintain the suspended solids in the aeration liquor at a high level in order to minimize the rate of change of the sludge volume index. However, from Figure 4 it is evident that the level of the aeration liquor suspended solids concentration must be relatively low because of the limited pumping facilities provided in most activated sludge plants. Thus, if I increases to a value that required more return sludge pumping capacity than is available in a plant, the aeration tank suspended solids must be reduced in order to keep the sludge from filling the final settling tanks and finally flowing out with the final effluent. This leads to the condition of varying the suspended solids to keep the return sludge ratio, r, within the limits provided by the plant. It is necessary, therefore, to study the effect of the new situation on the rate of change of the sludge volume index with time.

Sludge Volume Index—Time Relationship with Constant Sludge Volume in System

In order to develop the expression relating the sludge volume index and time, it is assumed that a constant volume of sludge is maintained in the activated sludge system if this sludge should be allowed to settle at any time for a period of 30 min. Thus, the amount of suspended solids in the system times the sludge volume index is equal to a constant. This leads to the condition shown in Figure 5, and to the differential equation:

$$B\,I_s = B\,I - 62.5\,Z\,\frac{da}{dt}\,I$$

By substituting the value of I from Eq. 4, transposing, and simplifying,

$$\frac{da}{dt} = \frac{B}{62.5\,Z}\left[\frac{-I_s\,a\,(1+r)}{10^6\,r} + 1\right]$$

—from which is obtained the differential equation

$$\frac{da}{1 - \dfrac{I_s\,a\,(1+r)}{10^6\,r}} = \frac{B}{62.5\,Z}\,dt$$

Integration of this expression and substitution of Eq. 4 in the result, followed by the processes of simplifying, transposing, and solving for I, gives

$$I = \frac{I_s}{1 - K_2\,e^{\frac{-B\,I_s(1+r)t}{10^6(62.5Z\,r)}}}$$

When $t = 0$, $I = I_0$. Therefore,

$$K_2 = 1 - \frac{I_s}{I_0}$$

and

$$I = \frac{I_s}{1 + \left[\dfrac{I_s}{I_0} - 1\right] e^{\frac{-B\,I_s(1+r)t}{10^6(62.5Z\,r)}}}$$

In order to make this rather clumsy expression useful, the following assumed values will be used to plot the relationship shown in Figure 6.

The values of B, I_0, and Z are those assumed for Figure 2. In addition, $r = 0.25$. The expression then becomes

$$I = \frac{I_s}{1 + \left[\dfrac{I_s}{I_0} - 1\right] e^{\frac{-I_s t}{10{,}000}}} \quad \ldots\ldots (5)$$

The values chosen for I_s are well within the limits of those encountered in plant operation. Using data obtained from the Peoria, Ill. activated sludge plant during 10 randomly chosen periods of sharply increasing sludge

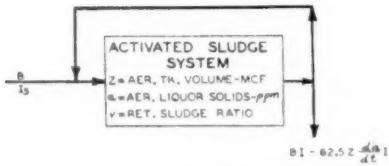


FIGURE 5.—Rate of change of sludge volume index in activated sludge system in which the settled volume of sludge is kept at a constant level.

volume index, values of I_s were computed. Of the 10 values, five were between 400 and 1,000, three were between 1,000 and 2,000, and two were greater than 2,000.

The situation shown in Figure 6 and by Eq. 5 implies a constant return sludge ratio and a waste activated sludge rate of flow such that the relationship of Eq. 4 is maintained.

Figure 7 shows the rate of change of sludge volume index under the two conditions of constant sludge solids and constant sludge volume in the system for a value of $I_s = 500$. The condition for constant sludge solids of levels corresponding to aeration liquor suspended solids of 1,000 and 3,000 p.p.m. is indicated. Note the desirability of the high aeration liquor suspended solids. This feature is also indicated in the early period of the constant sludge volume curve, where the aeration solids are high. The rate of increase is lower between 0 and 10 hr. than between 10 and 20 hr. because of the lower solids concentration during the second period than during the first period.

Waste Activated Sludge Flow—Sludge Density Relationship

The two basic equations for the sludge volume index (Eqs. 2 and 5) require definite conditions of waste activated sludge for the maintenance of the assumed constant sludge solids and volume. For constant sludge solids the rate of wasting activated sludge is derived by relating the rate of solids formed in the system to the product of the rate of wasting sludge and the concentration at which sludge is wasted. Thus,

$$8.34\ W\ r = B = 8.34\ S\ b$$

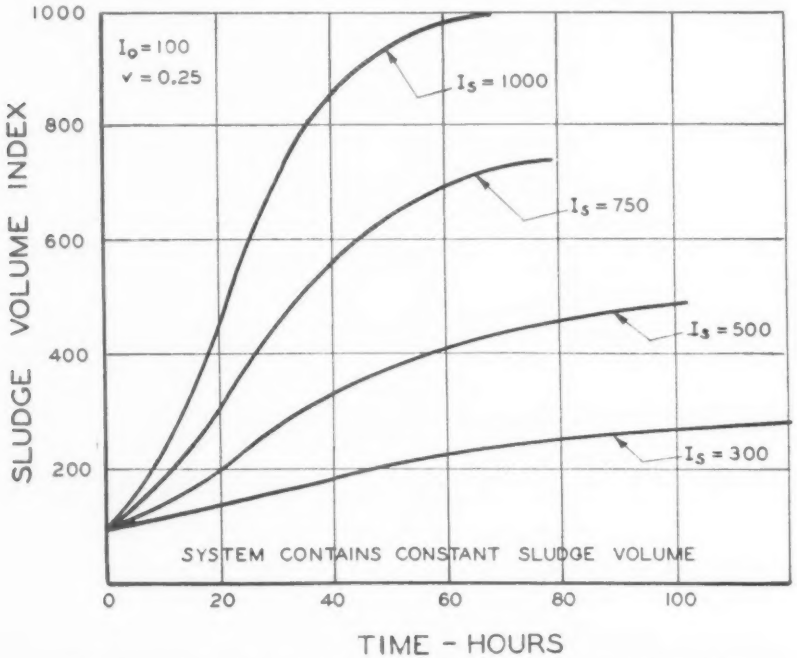


FIGURE 6.—Rate of change of sludge volume index for varying levels of the sludge volume index of the activated sludge formed.

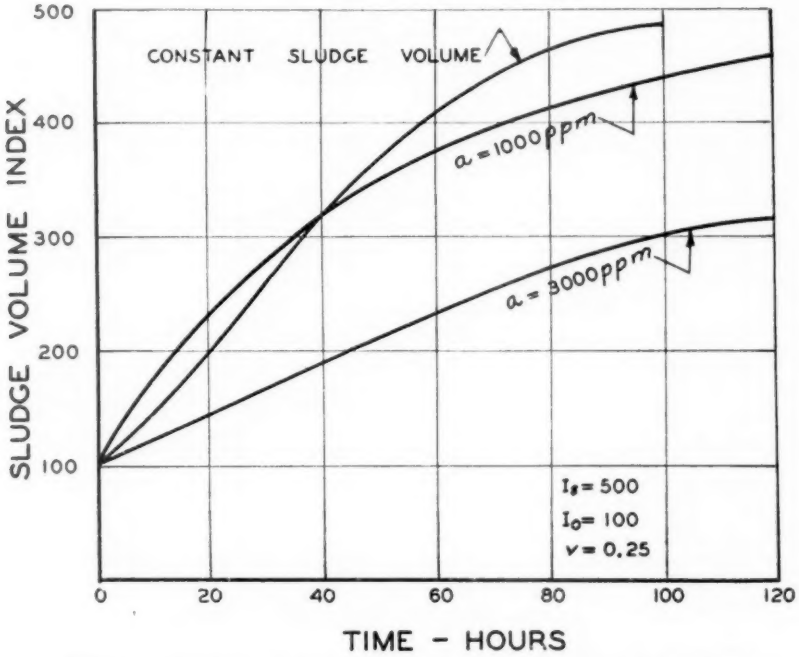


FIGURE 7.—Comparison of sludge volume index—time relationship with system at constant settled sludge volume and at two levels of constant aeration liquor suspended solids concentration.

By solving for W and substituting Eq. 3, this becomes

$$W = \frac{S\,b\,I}{10^6}$$

In like manner, it can be shown that under the condition of constant sludge volume

$$W = \frac{S\,b\,I_s}{10^6} \quad \ldots\ldots\ldots (6)$$

Figure 8 indicates the rate of change of W with I for the assumed values of $S = 1$ and $b = 150$. In order to keep the suspended solids in the aeration tanks at a constant level, it is necessary to have a considerable pumping facility for wasting sludge from the system. If this sludge is wasted to primary settling tanks or sludge concentration tanks, and thence to digesters, a new and interesting situation arises.

Separate Sludge Digestion—Activated Sludge Density Relationship

From the typical separate sludge digestion flow diagram shown in Figure 9 the relationship between the primary settling tank sludge (rate of flow P and solids concentration p), waste digested sludge (volume D and solids concentration d), and digester liquor (volume L and solids concentration m) can be established. The terms F and B are the rates of fresh solids removed, in lb./hr., and of activated sludge wasted, in lb./hr., respectively. Thus,

$$8.4\,P\,p = (F + B) + 8.4\,L\,m$$

Also,

$$8.4\,D\,d = (1 - K'')(F + B)$$

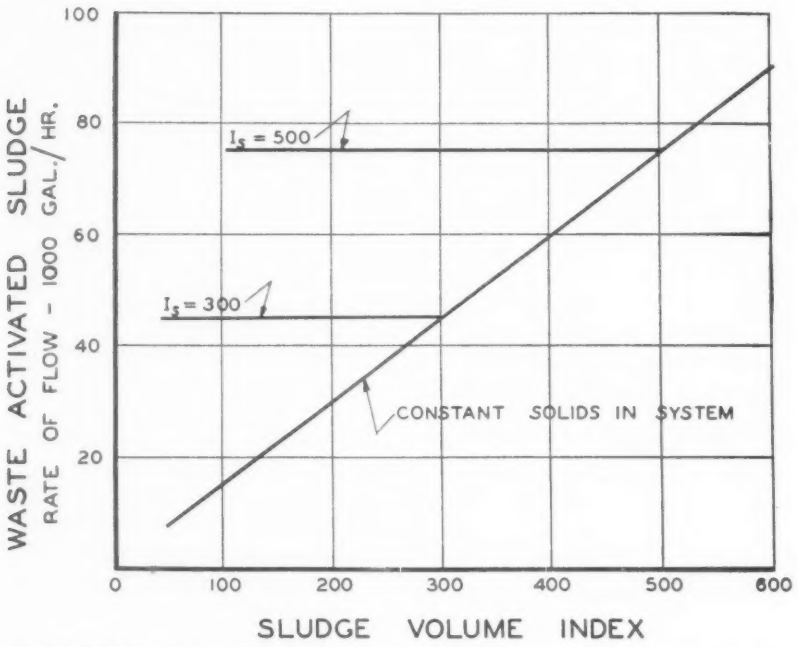


FIGURE 8.—Relationship between waste activated sludge rate of flow and sludge volume index for the assumed values of sewage flow of 1 mg. per hr. with suspended solids formed as activated sludge having a concentration of 150 p.p.m.

in which K'' is the reduction in total solids brought about by digestion. In the activated sludge-separate sludge digestion process this factor is in the order of 0.35 and this value of K'' is used herein. Thus,

$$8.4\,D\,d = 0.65\,(F + B)$$

In addition,

$$L = P - D$$

By the use of these equations the expression for the rate of flow of primary settling tank sludge—

$$P = \frac{\frac{F+B}{8.4}\left[1 - \frac{0.65\,m}{d}\right]}{p - m} \quad \ldots (7)$$

—is obtained. This is the equation of a hyperbola in which the primary settling tank sludge rate of flow, P, approaches infinity as the solids concentration of the digester liquor, m, approaches the solids concentration of the primary settling tank sludge, p.

Figure 10 shows the variation of the rate of flow of primary settling tank sludge, P, with the solids concentration of digester liquor, m, for three levels of primary tank sludge concentration, p. For purposes of constructing these curves it has been assumed that $F = B = 8.34\,S\,b$, where $S = 1$ and $b = 150$, and that the concentration of the waste digested sludge is 4.0 per cent.

It is well known that as the sludge volume index of the activated sludge increases, the concentration of the primary settling tank sludge decreases. Figure 10 indicates that if the system were in balance while pumping 3.5 per cent solids concentration primary settling tank sludge with a digester liquor solids concentration of 2.0 per cent, and

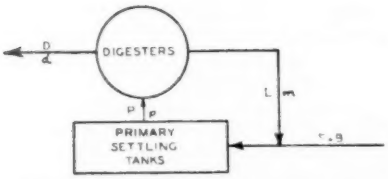


FIGURE 9.—Relationship of primary settling tank sludge rate of flow (P), and the concentration of solids in the waste digested sludge (d) digester liquor (m) and primary tank sludge (p).

a change in sludge index of the waste activated sludge reduced the primary settling tank sludge solids concentration to 2.5 per cent, the rate of flow of primary settling tank sludge will more than double. If this is not promptly accomplished, the sludge level in the primary settling tanks will increase and the sludge will ultimately leave the tanks with the primary effluent. This condition will require an increase in the waste activated sludge, which will further add to the load on the primary settling tanks. Thus, there is established a vicious cycle that cannot be remedied without losing activated sludge in the final effluent, or wasting activated sludge to a lagoon or tank capable of storing the large volume required.

Summary

This paper attempts to establish the quantitative relationships between the physical variables of the activated sludge process. It sets forth in mathematical form the equations relating the sludge volume index and the rates of flow in various parts of the process. It

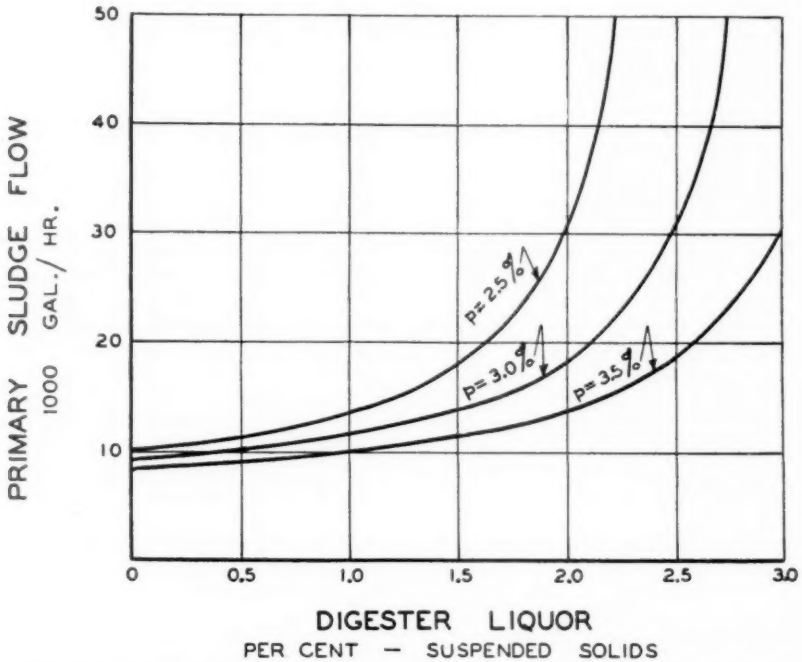


FIGURE 10.—Rate of flow of primary settling tank sludge, and digester liquor solids concentration, for three concentrations of primary tank sludge. (Concentration of waste digested sludge assumed 4.0%.)

establishes the desirability of maintaining aeration tank solids at a high level and points out the difficulties that arise because of limited return sludge and waste activated sludge pumping facilities. In addition, it suggests the difficult problem brought about by the returning of digester liquor to the primary settling tanks or sludge concentration tanks during periods of high sludge volume index activated sludge, particularly if this condition is accompanied by high solids concentration in the digester overflow.

Acknowledgment

This paper was made possible by the efforts of Dr. Marvin Moore, Professor of Mathematics, Bradley University, Peoria, Ill. All of the equations were derived by Dr. Moore, the author merely supplying the well-known fundamental relationships of the activated sludge process.

References

1. Ruchhoft, C. C., Butterfield, C. T., McNamee, P. D., and Wattie, Elsie, "Total Purification, Oxidation, Adsorption, and Synthesis of Nutrient Substrates by Activated Sludge." THIS JOURNAL, **11**, 2, 195 (Mar., 1939).
2. Bloodgood, Don E., "Concentration of Activated Sludge." THIS JOURNAL, **19**, 2, 202 (Mar., 1947).

QUANTITATIVE RELATIONSHIPS IN THE ACTIVATED SLUDGE PROCESS—A DISCUSSION

BY EARNEST BOYCE

Chairman, Department of Civil Engineering, University of Michigan, Ann Arbor, Mich.

Mr. Kraus has presented an interesting mathematical analysis of some of the variables that require control for the successful operation of the activated sludge process. The design and operation of a biological process that must operate under conditions of varying organic loading requires that there be a careful integration of all the variable factors. Mr. Kraus has summarized the basic problem of this process when he observes that "activated sludge may be thought of as a continuously changing biological medium in which different groups of organisms are increasing and decreasing in activity due to the varying nutrients in the wastes being purified and to varying environmental conditions."

If this problem can be simplified through the development of known relationships between variables that measure the effectiveness of the process, then the resulting curves should prove very useful in plant design and operation. The problem of sludge volume change has been the subject of much research, and many theories have been advanced with regard to basic cause and effect relationships.

The success of the process depends on the continuous return from the final sedimentation tanks to the aeration tanks of a sufficient amount of biologically activated sludge to biologically adsorb the organic portion of the sewage being added—this to be accomplished within the aeration contact time and under the conditions existing in the aeration tank.

When variations occur in the density of the returned sludge there must be a corresponding variation in the return sludge pumping rate if the concentration of aeration tank solids is to be maintained. If sludge density variations are normal in a sludge that is biologically active, then design data and operational controls must provide sufficient flexibility for extreme con-

ditions. If these variations represent an abnormal sludge condition, research and design interest should be directed toward insuring the production of a sludge of minimum density variation.

A sewage treatment plant will function successfully only when the design provides for biological workshops that insure at all times the proper working conditions for the biological life on which the process depends. Conversely, if the working environment is not uniformly satisfactory, the ability of the biological process to effect a satisfactory removal of organic material from sewage at times will be reduced, and may even fail.

It is suggested that the sudden bulking of activated sludge may result from a failure to evaluate properly all the factors and to provide the reserve biological workshop facilities to meet the unusual condition. It is suggested, also, that bulking of sludge is a phenomenon closely related to the sloughing of the biological film of a trickling filter, in that both conditions represent a breakdown in the workshop conditions necessary for the effective operation of the biological oxidation process. There is much to support the theory that trickling filter film is lost when the oxygen supply to the film surface is not sufficient to insure oxygen penetration to the base of the film and that the sloughing of the film results from the development of anaerobic biologic life at the base or rock contact surface of the film. There may be equally sound biological reasons for changes in the settling characteristics or in the sludge density index of activated sludge, as well as for the belief that successful operation of the process is dependent on maintaining a satisfactory biological working environment, despite the necessary variation in organic loadings that must be quickly adsorbed, and more slowly utilized for biological food or wasted from the system with the excess sludge.

Activated sludge must contain within the sludge particles biologically balanced colonies of living organisms capable of removing from the incoming sewage in the aeration tank organic matter in solution and fine suspension. The sludge particle must possess the capacity not only to adsorb the biologically oxidizable organic matter, but also to retain temporarily this material in its zoogloeal mass as a stored source of food for the slower biological assimilation—or, as commonly phrased, to oxidize it. Biologically, unicellular microscopic life adsorbs its food supply into the cell for the support of its life process only after the food substance has been chemically changed and liquified by the digestive enzymes exuded from the cell. Also, each individual cell has a definite and fixed capacity to utilize organic food. It follows, therefore, that there must be a certain time lag between adsorption and biological oxidation of the organic matter removed by the sludge particle—time required for the multiplication of the cells required to utilize the collected food. Because the process is aerobic, this biological life is dependent on a source of oxygen outside its food substance. Therefore, the water surrounding the sludge particle must have dissolved in it a sufficient amount of oxygen to supply this demand. If all sludge particles were to be continuously surrounded with water with a sufficiently high oxygen pressure to insure that the oxygen would diffuse through the particles, it would be reasonable to assume that those biologically balanced colonies of living aerobic organisms would function normally. Consequently, as a result of their life process, the biologically oxidizable food would be removed from the sewage. If the oxygen should fail to penetrate to all portions of the interior of the sludge particle, conditions would be favorable for the development of those forms of biological life that are able to obtain their necessary oxygen supply from the food substance, and inci-

dentally to release the gaseous by-products of their metabolism. When a dense activated sludge particle expands there is a change in the surface area-mass relationship. The particles may appear as smaller discrete particles that are less settleable because of this increase in the surface area-mass ratio, or they may have a decreased density due to the expanded sludge mass. In either case, the particles settle more slowly and evidence the characteristics of bulking.

Because the phenomenon of bulking in plants treating domestic sewage, without the interfering effects of industrial wastes, occurs more frequently under conditions of recognized excessive loading than under conditions of underloading, it appears logical to conclude that some vital factor in the biological workshop fails under conditions of overload. Under conditions of excessive loading one of the essential conditions for biological activity—the source of a useable food supply—is present in excess. The capacity of this mass (activated sludge) to adsorb biologically this organic food loading is fundamentally dependent on the metabolic activity of the organisms in the sludge, a factor that is not necessarily measured in terms of weight or volume of the sludge (1). The biological adsorptive capacity of the sludge returned to the aeration tank is probably more nearly measured in terms of the settleability, or of the sludge index, than in terms of the weight returned. The sludge index therefore appears to measure sludge vitality—a factor of sludge behavior that is probably more important than density alone.

Despite the amount of research work that has been conducted in the study of the biological factors in the activated sludge process, there is still need for continued study. The literature suggests that there is still confusion with regard to cause and effect relationships. It is difficult to establish the primary causes and the secondary effects when the changes are produced by so complicated a process. Mr. Kraus has made an interesting contribution to the research literature in this field.

Reference

1. Heukelekian, H., and Ingols, R. S., Discussion of "Studies of Sewage Purification. XIV. The Role of *Sphaerotilus Natans* in Activated Sludge Bulking." THIS JOURNAL, **13**, 1, 32 (Jan., 1941).

MAKE YOUR HOTEL RESERVATIONS FOR THE BOSTON CONVENTION

The Hotel Statler at Boston, headquarters for the Twenty-Second Annual Meeting of the Federation in October, will be able to accommodate all out-of-town registrants.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 17, and will close at noon on Thursday, October 20.

WRITE NOW FOR YOUR RESERVATIONS!

FACTORS AFFECTING THE EFFICIENCY OF ACTIVATED SLUDGE PLANTS *

By William E. Stanley

Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

The efficiency of activated sludge plants may be considered to be the relation of the removal of pollutional matter to the plant resources used to produce the result. This might also be designated as the plant performance. Satisfactory reduction in B.O.D. includes, in general, a reasonable reduction in suspended solids. Accordingly, B.O.D. removals may be used as an important single basic indicator of activated sludge sewage treatment plant performance.

However, inefficient removal of suspended solids by the final settling tanks adds an influential factor which cannot be evaluated by B.O.D. loadings, detention periods, mixed liquor concentrations, air quantities, or other factors related only to the aeration tanks. Nevertheless, despite the fact that the present B.O.D. test is a crude indicator in need of improvement, the routine analytical data based on this test from operating plants appear to be the best presently available basic information for the study of activated sludge plant results.

Plant Scale Investigations

An investigation of operating data from activated sludge plants was initiated in the fall of 1946. Through the courtesy of plant superintendents, chemists, and designing engineers many data have been assembled from a number of representative municipal plants. During 1946–47 Berberich (1) made an initial study of data from 27 plants. During 1947–48 Samuel (2) continued the investigation, using monthly average data from 15 plants. An expansion of the earlier studies has been summarized recently by Stanley and Berberich (3) based on operating data from 31 plants. This discussion is based on yearly average data from 26 plants.

Much basic knowledge has resulted over the past 10 or more years from extensive plant scale investigations at Chicago, New York, Milwaukee, Indianapolis, and elsewhere, each investigation being related primarily to the specific and peculiar local conditions. Several individual plant operators have published excellent analyses of the operation of their particular plants.

There are on record few studies based on combined operating results from any extended number of plants. An A.P.H.A. Committee report (4) published in 1942 was one of the earliest efforts to relate B.O.D. removals from several plants in different cities to detention periods and to air quantities. Data from nine relatively large plants were used.

A National Research Council report (5) includes an excellent analysis of operating data from five activated sludge plants at military installations and proposes a measurement of performance based on per cent B.O.D. removals related to a composite loading unit of pounds B.O.D. per 1,000 lb. of suspended solids in the aeration tank per hour of aeration.

Over-all Plant Performance

The activated sludge process is capable of producing a relatively high degree of sewage treatment in terms of

* Presented at the Twenty-first Annual Meeting, Federation of Sewage Works Assns.; Detroit, Mich.; Oct., 1948.

TABLE I. Sewage Flows, Analytical Data, and Percentage Removals for 26 Activated Sludge Plants in 23 Cities

Plant	Time of Record		Sewage Flows (m.g.d.)			Laboratory Analytical Data (p.p.m.)							Removals (%)					
						5-day B.O.D.			Suspended Solids				Prim. Sed.		Aer. and Fin. Tks.[1]		Entire Plant[2]	
	Dates	Duration (yr.—mo.)	Raw to Plant	Settled to Aeration	Mixed Liquor	Raw	Settled	Final	Raw	Settled	Final	Mixed Liquor	B.O.D.	Sus. Sol.	B.O.D.	Sus. Sol.	B.O.D.	Sus. Sol.
Ann Arbor, Mich. Act. Sl.	1944–46	2—4	5.0	5.0	6.6	223	182	19	218	128	12	1,844	18.4	41.2	89.6	90.7	91.5	94.5
Ann Arbor, Mich. Act. Sl.	1947	1—0	6.6	6.5	8.5	201	169	13	176	107	11.8	1,850	...	...	...	...	...	...
Ann Arbor, Mich. Pl. Aer.	1945–46	0—8	5.35	5.3	5.3	218	171	63	200	103	35	150	...	...	...	...	...	...
Austin, Tex.	1944	1—0	4.68	4.68	7.26	289	150	22.9	264	94	9.8	1,515	48.1	64.4	84.8	89.6	92.1	96.2
Baltimore, Md.	1945	1—0	108.16	10.64	12.93	248	217	14	227	92	8	937	12.5	59.5	93.6	91.3	94.4	96.5
Chicago, Ill. So. West	1946	1—0	356.0	288.0	426.0	171	129	11	226	...	14	1,930	24.6	...	91.5	...	93.6	93.8
Chicago, Ill. No. Side	1946	1—0	197.5	197.5	244.9	114	97	6	142	...	8	2,400	15	...	93.8	...	94.7	94.4
Chicago, Ill. Calumet	1946	1—0	73.7	71.8	90.4	104	94	9	132	...	11	2,190	10	...	90.4	...	91.3	91.7
Cleveland, Ohio—Easterly	1940–45	6—0	93.4	86.9	108.5	151	91.5	12	243	146	13.3	2,180	39.4	39.9	86.9	90.8	92.0	94.4
Cleveland, Ohio—Easterly	1945	0—7	92.5	90.2	115.7	190	94	6.9	222	...	9.7	1,248	...	...	...	...	...	...
Decatur, Ill.	1946	0—11	12.21	3.92	4.64	219	157	20	266	78	42	2,180	28.3	70.7	87.6	46.2	90.7	84.2
Decatur, Ill.	1947	0—10	...	4.70	5.57	224	160	12	268	...	38	2,342	...	...	...	...	...	...
Fort Wayne, Ind.	1941–45	5—0	17.47	14.92	19.49	204	161	15.2	236	151	16.6	2,420	21.1	36	91.0	89.1	92.6	93.0
Gary, Ind.	1941–45	5—0	20.0	19.0	25.3	150	77	8	273	101	7.2	1,325	48.7	63	89.6	92.9	94.4	97.2
Hagerstown, Md.	1943–46	4—0[3]	3.87	3.87	5.09	206	254[4]	33.6	157	286[4]	13	1,808	...[4]	...[4]	86.8	95.5	83.7	91.7
Hammond, Ind.	1942–46	5—0	21.0	20.2	30.7	180	135	11.6	220	152	17	2,196	25.0	30.9	91.5	88.8	93.5	92.3
Jackson, Mich.	1942–46	5—0	8.12	8.04	9.28	145	118	6	216	144	16	2,801	18.6	33.3	94.9	88.8	95.8	92.3
Madison, Wis.	1947	1—0	7.60	7.60	11.52	229	157	36	210	...	19	1,094	31.4	...	77.1	...	84.3	86.2
Marion, Ind.	1942–45	6—4	4.2	3.92	5.13	188	134	12.7	241	117	12	2,625	28.7	51.4	89.7	89.8	93.4	95.0
Marshalltown, Iowa	1943–46	3—0	3.14	3.35	4.40	337	177	37	395	130	49	2,500	47.4	67.1	79.2	62.3	89.0	87.6
Milwaukee, Wis. West	1945	1—0	65.4	65.4	81.66	332	332	18	315	315	20	3,000	...	...	94.6	93.6	94.6	93.6
Milwaukee, Wis. East	1945	1—0	56.02	56.02	68.04	332	332	17	315	315	15	3,000	...	...	94.8	95.2	94.8	95.2
Omaha, Neb.	1946	1—0	2.54	2.54	4.09	296	128	25	422	149	30	1,720	56.7	64.6	80.5	79.9	91.6	92.8
Peoria, Ill.	1942–46	5—0	14.6	14.1	19.4	324	229	22	322	146	20	1,640	29.3	54.6	90.5	86.6	93.3	94.0
Pontiac, Mich.	1946	1—0	8.2	4.8	5.8	219	125	12.3	208	73	10	1,200	42.8	64.9	90.0	86.3	94.5	95.2
Richmond, Ind.	1942–46	5—0	5.45	5.45	7.0	138	113	6	179	92	16	1,680	18.1	48.6	94.7	82.6	95.9	91.1
San Antonio, Tex.	1945–46	2—0	36.8	24.9	33.1	224	129	17	260	162	21	1,150	42.3	37.7	86.8	87.1	92.5	92.0
Springfield, Ill.	1942	1—0	9.2	9.2	12.7	103	74	8	132	81	8	1,580	28.1	38.6	89.3	90.2	92.2	93.9
Springfield, Ill.	1937–41	5—0	7.8	7.8	9.95	167	132	13	185	120	11	1,683	...	...	...	...	...	...
Syracuse, N. Y.	1947	1—0	4.31	4.31	5.44	353	236	32	232	...	13	2,218	33.1	...	86.4	...	91.0	94.4
Two Rivers, Wis.[5]	1946	1—0	0.98	0.98	1.45	168	114	10.4	207	86	17	1,500	32.1	58.4	90.9	80.3	93.9	91.8

[1] Based on settled sewage. [2] Based on raw sewage. [3] 7 months in each year. [4] Settled sewage stronger than raw due to wasted activated sludge. [5] Averages of results of both plants.

B.O.D. and suspended solids removals. Illustrative data averaged over periods of 1 to 5 yr. from 26 plants in 23 cities (Tables I and II) indicate over-all pollutional matter removals as high as 95 per cent. These are standard activated sludge process plants. The numbers of plants for various ranges of operating results have been as follows:

Magnitude of Removal*	Number of Plants B.O.D.	Suspended Solids
Up to 95 per cent	5	6
Above 92 per cent	17	20
Above 90 per cent	23	23
Between 87 and 90 per cent	3	3
Total plants	26	26

* Over-all plant performance

Thus, averaged over periods of 1 to 5 years, about 69 per cent of the number of plants produced better than 92 per cent B.O.D. removal, and 88 per cent of the number removed more than 90 per cent of B.O.D. and suspended solids, from the sewage treated by the 26 plants. Results for each plant varied considerably from month to month during the periods of record.

It is not entirely correct to separate the performance of primary sedimentation units from the performance of aeration and final sedimentation tanks, but doing so simplifies the investigational problem. On this basis the operating results of the 26 plants show numbers of plants with various ranges in performance, based on B.O.D. and suspended solids removals, in terms of concentrations in the sewage applied to the aeration tanks, as follows:

Magnitude of Removal*	Number of Plants B.O.D.	Suspended Solids
Up to 95 per cent	4	2
Above 92 per cent	8	4
Above 90 per cent	16	10
Between 83 and 90 per cent	7	7
Below 83 per cent	3	4
Total plants	26	21

* Based on settled sewage.

These data show a wider spread in the range of results for performance of the aeration and final tanks than do the over-all plant results. Some part of this may be due to variations in type, size, and effectiveness of the primary sedimentation (or screening at Milwaukee, Wis.). Also, the settling efficiency of the final tanks has an effect. In general, other factors appear to be more influential.

Removals by Primary Settling Tanks

The results of primary settling tank operation vary considerably, in part due to design factors (such as detention periods, overflow rates, and velocity-current regulation). However, a more important factor is the practice, in many plants, of wasting the excess activated sludge, and the disposal of digestion tank supernatant liquor into the primary tanks.

The raw sewage analyses do not include the pollutional matter supplied from the excess sludge and the digester supernatant. Thus, the actual performance of the primary tanks is unknown. In certain cases, as at Hagerstown, Md. (Table I), the primary tank effluent contains more pollutional matter than the raw sewage. Available data (Table I) show primary settling tank removals ranging from 12 to 48 per cent of the B.O.D. and from 31 to 71 per cent of the suspended solids.

Some plants, such as the two Milwaukee plants, have only fine screens in place of sedimentation. Other plants (such as the Chicago, Ill., North Side and Calumet plants), have very short detention periods. These conditions surely affect the performance of the aeration and final tanks.

Performance of primary tanks and the aeration-final tanks undoubtedly is closely interrelated. However, more complete analytical data, particularly analysis of the composite sewage, including wasted sludge and digester overflow, would be needed to determine

TABLE II. B.O.D. Load on Aeration Tanks

Plant	Year	B.O.D. (lb./day)		B.O.D. Removals (lb./day)			Effluent B.O.D. (lb./day)	Volume of Aer. Tks. (1,000 c.f.)	B.O.D. Appl. to Aer. (lb./1,000 c.f.)	Mixed Liquor (m.g.d.)	Aeration Period[1] (hr.)
		Raw Sewage	To Aer. Tanks	Primary Tanks	Aer. and Fin. Tks.	Total					
Ann Arbor, Mich. (Act. Sl.)	1944–46	9,300	7,580	1,720	6,790	8,510	790	194.4	39.0	6.6	5.3
Ann Arbor, Mich. (Act. Sl.)	1947	10,900	9,160	1,740	8,450	10,200	700	194.4	47.1	8.5	4.1
Ann Arbor, Mich. (Pl. Aer.)	1945–46	9,820	7,700	2,170	4,860	6,980	2,840	194.4	39.6	5.3	6.6
Austin, Tex.	1944	11,280	5,850	5,430	4,960	10,300	890	253[2]	21.5	7.26	6.1
Baltimore, Md.	1945	22,030	19,280	2,750	18,040	20,790	1,240	6.68	28.8	12.93	9.27
Chicago, Ill. (So. West)	1946	410,400	309,600	100,800	283,200	384,000	26,400	14,700	21.0	426.0	5.9
Chicago, Ill. (No. Side)	1946	188,000	160,000	28,000	150,000	178,000	10,000	7,220	22.1	244.9	5.3
Chicago, Ill. (Calumet)	1946	62,200	56,200	6,000	50,800	56,800	5,400	2,610	21.6	90.4	5.2
Cleveland, Ohio—Easterly	1940–45	109,000	66,000	43,000	57,300	100,300	8,700	3,790	17.4	108.5	6.2
Decatur, Ill.	1946	7,160	5,140	2,020	4,490	6,510	650	169[3]	30.3	4.64	4.74
Decatur, Ill.	1947	8,780	6,270	2,510	5,800	8,310	470	113[2]	35.8	5.57	3.82
Fort Wayne, Ind.	1941–45	25,400	20,050	5,350	18,160	23,510	1,890	843	23.7	19.49	7.7
Gary, Ind.	1941–45	23,750	12,200	11,550	10,930	22,480	1,270	628	19.4	25.3	4.4
Hagerstown, Md.	1943–46	6,700	8,200	...	7,120	7,100	1,100	185.8	44.1	5.09	6.7
Hammond, Ind.	1942–46	30,400	22,800	7,600	20,800	28,400	2,000	1,149	19.9	30.7	7.2
Jackson, Mich.	1942–46	9,720	7,910	1,810	7,510	9,320	400	300	26.4	9.28	5.8
Madison, Wis.	1947	14,510	9,950	4,560	7,670	12,230	2,280	376	26.4	11.52	6.0
Marion, Ind.	1942–45	6,150	4,380	1,770	3,970	5,740	410	124	35.4	5.13	4.34
Marshalltown, Iowa	1943–46	9,400	4,940	4,460	3,910	8,370	1,030	172.8	28.6	4.4	7.03
Milwaukee, Wis. (West)	1945	181,000	181,000	...	171,200	171,200	9,800	3,850	47.0	81.66	8.45
Milwaukee, Wis. (East)	1945	155,000	155,000	...	147,050	147,050	7,950	2,980	52.0	68.04	7.88
Omaha, Neb.	1946	6,270	2,710	3,560	2,180	5,740	530	172	15.8	4.09	7.6
Peoria, Ill.	1942–46	38,100	26,980	11,120	24,400	35,520	2,580	618[2]	34.5	19.4	5.73
Pontiac, Mich.	1946	8,760	5,000	3,760	4,510	8,270	490	154	32.5	5.8	4.77
Richmond, Ind.	1942–46	6,270	5,140	1,130	4,870	6,000	270	248.8	20.6	7.0	6.4
San Antonio, Tex.	1945–46	46,500	26,800	19,700	23,270	42,970	3,530	1,025[2]	25.0	33.1	5.5
Springfield, Ill.	1942	7,900	5,700	2,200	5,090	7,290	610	365	15.6	12.7	5.5
Springfield, Ill.	1937–41	10,840	8,570	2,280	7,720	10,000	840	365	23.5	9.95	6.6
Syracuse, N. Y.	1947	12,700	8,470	4,230	7,305	11,535	1,165	177	47.8	5.44	6.0
Two Rivers, Wis.	1946	1,377	934	443	849	1,292	85	68.4	13.7	1.45	8.44

[1] Based on mixed liquor through aeration tank volume.
[2] Aeration tank volume used for mixed liquor.
[3] Combined aeration and reaeration volume.

closely the relative influence of the two plant subdivisions. It is suggested that plant operators give attention to and record the actual performance of the primary settling tanks (or screens), in order that more complete knowledge may be available to explain variations in plant performance.

Outline of Factors

Influential factors may be placed loosely into three groups: (1) Factors generally beyond the control of the plant designer or operator; (2) Factors partially controlled by the plant designer; and (3) Factors partially within the control of the plant operator. It would be audacious to attempt to cover herein all factors affecting activated sludge plant performance. Accordingly, only a few factors closely related to plant design are emphasized.

Roughly, in order of relative influence, the factors to which the plant designer might give attention include:

1. Sewage quantity variations; that is, rates of flow and pollutional matter concentrations;
2. Type or character of pollutional matter;
3. B.O.D. loading per unit volume of aeration tanks (pounds applied per 1,000 c.f.);
4. Aeration contact period (hours);
5. Suspended solids concentration in the aeration tanks (mixed liquor);
6. Air supply quantities; and
7. Other important factors, such as the character and quantity of returned activated sludge, the sedimentation efficiency, the temperature, and the amount and degree of nitrification.

Sewage Quantity Variations

Large or sudden increases in rates of flow or in concentration of pollutional matter long have been considered detrimental factors in the operation of activated sludge plants. Designers have attempted to guard against these by rather unsatisfactory empirical and arbitrary procedures, such as providing capacities for maximum rates of flow not more than 1½ times the average basis of design flow (8), with greater flows by-passed around the plant.

Thus, at Leominster, Mass., sewage flows in excess of 4.0 m.g.d. are by-passed directly to the river. At Ann Arbor, Mich., flows in excess of 8.0 m.g.d. are by-passed.

Some experiences at Syracuse, N. Y., and Ann Arbor may be reasonably typical to illustrate the effects of sewage flow variations.

Weekly average data published by Mann (6) for the Ley Creek plant at Syracuse (Figure 1) illustrate the effect of quantity variations averaged over time periods of a week in length. During a period of 24 weeks—November 5, 1944, to April 28, 1945—with plain aeration, a doubling of the weekly average daily rate of sewage flow resulted in a 35 per cent less removal of B.O.D., while the B.O.D. concentration dropped to about 50 p.p.m. as compared to 172 p.p.m. average for the 24 weeks. Similar results occurred during the 12-week period March 4 to May 20, 1946, with activated sludge operation (Figure 1) when the B.O.D. pollutional matter percentage removal values increased about 18 per cent (82 to 97 per cent) while the rate of flow reduced by about 37 per cent (6.59 m.g.d. to 4.14 m.g.d.) and the B.O.D. concentration rose from 37 p.p.m. to 313 p.p.m.

At Ann Arbor, Witcher has reported (7) effects of hourly variations in flows and B.O.D. concentration. During 1947, hourly rates were greater than 8.0 m.g.d. for 9 hr. during the average day. This was the maximum rate of flow taken through the plant. Thus, the by-pass sewer was in frequent operation. Hourly B.O.D. ranged from a minimum of 50 p.p.m. to a maximum of 610 p.p.m. He states:

"Peak flows are of utmost importance in activated sludge treatment as far as the settling rate of sludge is concerned. . . .

it has been necessary to maintain a fast settling sludge at all times since our final settling time is only about an hour theoretically. Actually the time is much less than this since at high rates (of flow) short-circuiting becomes aggravated."

Although changes in rates of flow or amounts of pollutional matter averaged over short periods of time show substantial influence on plant efficiency, sometimes results averaged over longer time periods do not show the same influence. Thus, 1945 data for Cleveland, Ohio averaged over monthly periods seem to show influences of other factors than quantity variations. Perhaps temperature or some other factors are more influential. Although monthly average flow rates increased from 84 m.g.d. during January and February to 103 m.g.d. during June and the sewage strength remained substantially the same, B.O.D. removals increased from 88 up to 98 per cent.

This factor of variations undoubtedly is a most important one. Exact quantitative determination of the direct effect of sewage variations may result when methods are devised to measure more closely the character of pollutional matters and the interrelation of the various influential factors. However, it must be controlled by storage or recycling larger quantities of sewage or sludge.

Character of Pollutional Matter

A comparison of the performance of two groups of plants is given by Table III. One group of 10 plants treating mainly domestic sewage shows B.O.D. removals through aeration and final tank above 90 per cent, with an average for all 10 plants of 92.5 per cent. The second group of 7 plants treating sewage with larger quantities

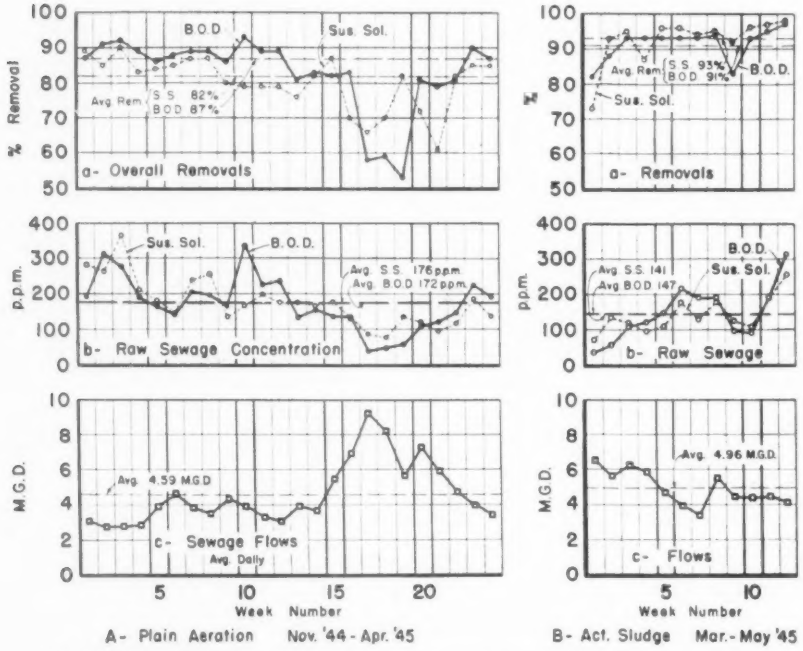


FIGURE 1.—Effect of flow and B.O.D. quantity variations at Syracuse, N. Y.

TABLE III.—Comparison of B.O.D. Removals by Plants Treating Domestic Sewage and Plants Treating Industrial Wastes

Plant	Year of Data	B.O.D. Appl. to Aer. Tanks		B.O.D. Removal (%)	
		p.p.m.	lb. 1000 c.f.	Aer. and Fin. Tks.[1]	Over-all[2]
(a) Plants Treating Mainly Domestic Sewage					
Ann Arbor	1947	169	47.1	92.3	93.6
Baltimore	1945	217	28.8	93.6	94.4
Chicago					
So. West	1946	129	21.0	91.5	93.6
No. Side	1946	97	22.2	93.8	94.7
Fort Wayne	1941–46	161	26.0	91.0	92.6
Hammond	1942–46	135	19.8	91.5	93.5
Jackson, Mich.	1942–46	118	26.3	94.9	95.8
Marion	1942–45	134	35.3	90.5	93.4
Richmond, Ind.	1942–46	113	24.1	94.7	95.7
Two Rivers	1946	114	13.7	90.9	93.9
Unweighted Average				92.5	94.1
(b) Plants Treating Substantial Amounts of Organic Industrial Wastes					
Austin	1944	150	21.5	84.8	92.1
Decatur	1946	157	30.3	87.2	90.7
Madison, Wis.	1947	157	26.2	77.1	84.3
Marshalltown	1943–46	177	28.6	79.2	89.0
Omaha	1946	128	15.7	80.5	91.6
San Antonio	1945–46	129	25.0	86.8	92.5
Syracuse	1947	236	41.5	86.4	91.0
Unweighted Average				83.1	90.2

[1] Based on settled sewage.
[2] Based on raw sewage.

of industrial wastes has an average of 83.1 per cent B.O.D. removal.

Chemical constituents of sewage materially affect plant performance under certain conditions. For example, at Cranston, R. I., the high content of brewery wastes has virtually put the activated sludge plant out of operation. Some research on the effect of various chemicals has been reported, but more is needed before definite evidence will be available.

Nitrogen appears to be influential in plants treating domestic sewage, mainly by producing higher B.O.D. values in plant effluents due to nitrifying organisms in B.O.D. test bottles when active nitrification is taking place in the sewage treatment plants. Mohlman (9) first called attention to the effect of nitrification on plant performance. Sawyer and Bradney (10) and Hurwitz *et al.* (11) have suggested two different modifications of the B.O.D. laboratory technique to avoid nitrification in the B.O.D. bottles during incubation. Hurwitz *et al.* (11) presented data showing lower values of effluent residual B.O.D. ranging from about 4 to 75 per cent, averaging 31.5 per cent, for Chicago sewage plant effluent by the acid modified laboratory technique compared to the standard procedure. Kraus (12) has tried modified B.O.D. tests, his earlier results showing residual B.O.D. values 20 to

30 per cent lower than standard results. Hatfield (13) has tried both the acid and the pasteurization modifications of the B.O.D. laboratory technique, finding a reduction in residual B.O.D. values, by either method compared to the standard B.O.D. test, of 40 to 50 per cent during January and an average of about 17 per cent during July.

Witcher (14) has tried the acidified B.O.D. method during 1948, finding the B.O.D. results in line with suspended solids results regardless of the degree of nitrification of the plant effluent. His earlier results appear to be about 50 per cent lower than by the standard B.O.D. procedure.

A limited number of data, reported by a few plants, showing effluent nitrates compared to B.O.D. removals (Table IV) shows some tendency toward higher B.O.D. removals with lower values of nitrates in plant effluents.

Definite evidence has not yet been obtained on the basis of data averaged over periods of one or more years. Additional study will be required, probably using data averaged over shorter periods of time in order that temperature and other seasonal influences may be properly considered.

B.O.D. Loadings

Obviously some relation must exist between plant loading and plant performance, but a proper loading factor has not yet been standardized. Rates of flow and detention periods have been used for many years. Recently, B.O.D. loadings have been proposed in terms of pounds per 24 hr. per 1,000 cu. ft. of aeration tank volume.

Greeley (15) suggested 30 lb. per 1,000 cu. ft. as a basis of design. Recent studies (3) of data from 27 plants seem to indicate this to be an oversimplification, but Greeley's factor seems to be a reasonably conservative basis of design with higher loading allowance likely if all influential fac-

TABLE IV.—Comparison of B.O.D. Removal and Nitrates in Plant Effluents

Plant	Year	Settled Sewage B.O.D. (p.p.m.)	Plant Effluent (p.p.m.)		B.O.D. Removal (%)
			B.O.D.	Nitrates	
Ann Arbor, Mich.	1944–46	182	19	5–10	89.6
	1947	169	13	4.7	92.3
Austin, Tex.	1944	150	23	4.4	84.8
Chicago, Ill.					
So. West	1946	129	11	0.9	91.5
No. Side	1946	97	6	0.9	93.8
Calumet	1946	94	9	0.7	90.4
Cleveland, O.	1940–45	92	12	3.4	86.9
Decatur, Ill.	1946	157	20	1.3	87.2
	1947	160	12	0.7	92.2
Hammond, Ind.	1942–46	135	12	4.5	91.5
	1946	170	14	5.7	91.8
Jackson, Mich.	1942–46	118	6	1.4	94.9
	1946	107	4	0.0	96.2
Madison, Wis.	1947	157	6	4.5	77.1
Milwaukee, Wis.					
West Plant	1945	332	18	1.6	94.6
East Plant	1945	332	17	1.1	94.8
Pasadena, Cal.	1945–46	165	16	2.0	90.5
Peoria, Ill.	1942–46	229	22	2.4	90.5
	1946	244	18	3.1	92.8
San Antonio	1945–46	129	17	0.1	86.8
Springfield, Ill.	1942	74	8	5.0	90.6

TABLE V.—B.O.D. Removals by Aeration and Final Tanks Related to B.O.D. Loadings [1]

Plant		Time of Record		B.O.D. in Aer.-Fin. Tks.	
Location[2]	No.	Year	Length	Loading (lb. 1,000 c.f.)	Removal (%)
Ann Arbor	1	1947	1 yr.	47.8	92.3
Austin	2	1945	6 mo.	30.8	91.8
Cleveland	3	1945	7 mo.	18.8	92.7
Decatur	4	1947	10 mo.	35.8	92.2
Ft. Wayne	5	1941–47	7 yr.	26.0	91.1
Gary	6	1946	6 mo.	21.6	90.3
Hammond	7	1946	1 yr.	24.1	91.8
Jackson	8	1946	1 yr.	20.9	96.2
Madison[3]	9	1947	1 yr.	26.2	77.0
Marion	10	1946	10 mo.	43.1	92.5
Muncie	11	1946–47	8 mo.	28.7	90.4
Omaha[3]	12	1946	11 mo.	15.7	82.4
Peoria[4]	13	1946	1 yr.	40.7	92.8
San Antonio[3]	14	1945–46	2 yr.	25.0	86.8
Springfield	15	1942	10 mo.	13.8	90.6

[1] Based on monthly averages and omitting months of disturbed operation.
[2] See Table I.
[3] Large amounts of packinghouse wastes included.
[4] Special loading studies.

tors were satisfactorily integrated. Short-time loadings up to about 80 lb. per 1,000 cu. ft. of aeration tank volume have been used at Peoria and Decatur, Ill., with no apparent reduction in percentage B.O.D. removals. Torpey (16) has reported B.O.D. loadings at the Bowery Bay plant (New York City) up to 84 lb. per 1,000 cu. ft., with 90 per cent B.O.D. removals. Other data published by Greeley (17) from plants with less concentrated sewage indicate a decided dropping off in B.O.D. percentage removals for B.O.D. loadings above 30 lb. per 24 hr. per 1,000 cu. ft. of aeration tanks.

Samuel (2) has carefully studied monthly data from 15 activated sludge plants (Table V), using selected data for a number of months during which there was no evidence of plant upsets due to special difficulties. The B.O.D. removals averaged over periods ranging from 6 months to 7 years, plotted against B.O.D. loading in pounds per 24 hr. per 1,000 cu. ft. of aeration tank volume (Figure 2) show no trend toward a lesser percentage B.O.D. removal with B.O.D. loadings ranging from 15 to 50 lb. per day. Three plants (Madison, Wis., 9; Omaha, Nebr., 12; and San Antonio, Tex.; 14) show substantially lower B.O.D. removal than the other 12 plants. This has been attributed to the packinghouse wastes in these three plants.

These selected data and other similar data recently published (3) for a larger number of plants indicates that, in addition to B.O.D. loadings, other influential factors must be included.

Aeration Contact Period

No exact method has been devised to measure accurately the average time sewage is in contact with activated sludge, in the presence of ample dissolved oxygen in the aeration tanks. Therefore, an index number, designating the aeration period in hours, is computed by dividing the aeration tank volume by the average hourly flow of mixed liquors. This aeration period is only an approximate index of the actual aeration contact time.

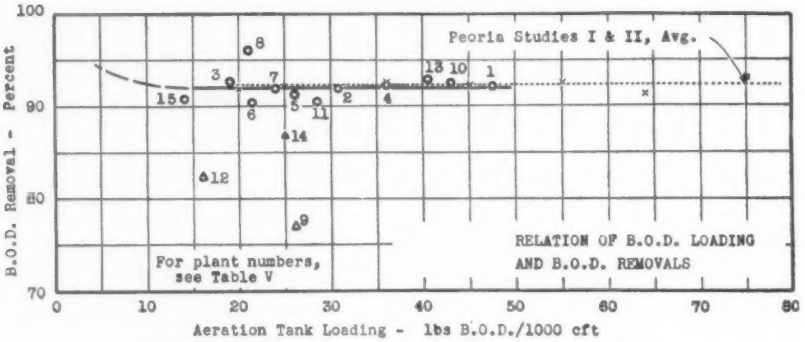

Peoria Studies I & II, Avg.
RELATION OF B.O.D. LOADING
AND B.O.D. REMOVALS
For plant numbers,
see Table V
B.O.D. Removal - Percent
Aeration Tank Loading - lbs B.O.D./1000 cft

FIGURE 2.—Relation of B.O.D. loading and B.O.D. removals.

A direct comparison between plant performance, in terms of yearly average per cent removal of B.O.D., and aeration hours (Figure 3) indicates a tendency toward lower efficiencies for aeration periods shorter than 4 or 5 hr. This is indicated more definitely by the upper dashed line based on data from Syracuse, N. Y. (21). However, with mixed liquor suspended matter concentrations greater than 1,500 p.p.m. there appears little improvement in B.O.D. removals for aeration periods greater than 5 hr. Plain

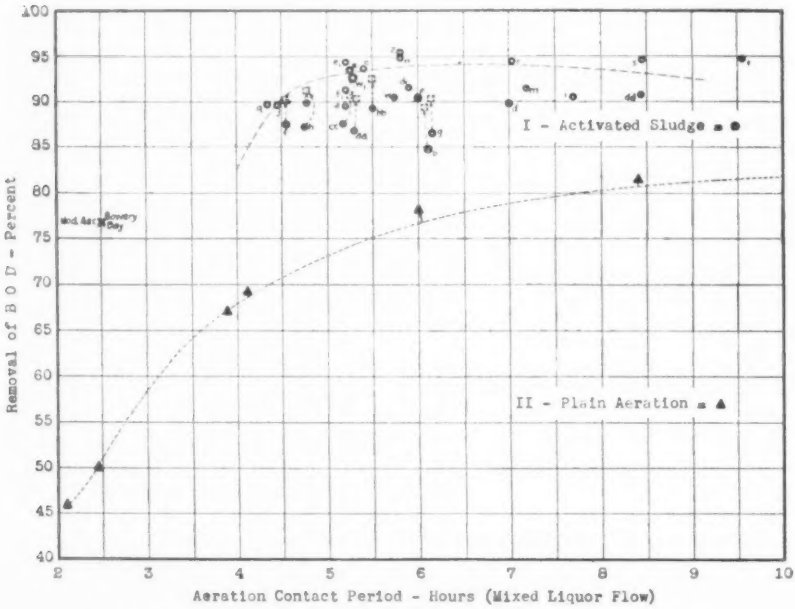


FIGURE 3.—Relation of aeration contact period and B.O.D. removal.

aeration operation at Syracuse (6) showed a definite reduction in percentage removal of B.O.D. for aeration periods less than 7 or 8 hr. The scattering of the plotted points (Figure 3) indicates that other factors must be involved along with aeration period to influence the efficiency of activated sewage treatment.

Suspended Solids Concentration in Aeration Tank

The concentration of activated sludge solids in the aeration tank mixed liquor definitely affects plant efficiency (Figure 4). The influence on B.O.D. removals does not increase greatly for suspended solids concentrations above 1,500 p.p.m. Doubling the suspended solids concentration (1,500 to 3,000 p.p.m.) appears to increase the percentage B.O.D. removal from 91 to 95 per cent. However, the suspended matter concentration appears to be more influential for concentrations less than 1,500 p.p.m., particularly if plain aeration and modified aeration data are included.

A number of data (Table VI) on mixed liquor concentrations and B.O.D. removals have been selected for plants and time periods when known upsetting influences were at a minimum. In this tabulation have been collected also published data on operation with low concentrations of suspended solids in aeration tanks. These latter data indicate a very definite logarithmic relationship between aeration tank solids and plant efficiency. Two straight "best fit" lines intersecting at a suspended solids concentration of 1,500 p.p.m. graphically represent quite well the several data when plotted on logarithmic paper (see Figure 4).

The biological activity and settling character of the activated sludge solids are important factors. Some progress has been made by Bloodgood (18) and others in quantitative measurements of sludge activity, but more such studies are needed before any definite relationship can be determined.

Kraus (19) has proposed the use of digested sludge and digester supernatant liquor to control the settling characteristics of activated sludge. This has been tried experimentally elsewhere.

Air Quantities

Air quantities, more generally reported in cubic feet per gallon of sewage, range from less than 0.5 to 1.9 cu. ft. per gal. Graphically summarized (Figure 5), the average air supply quantities at existing plants show a wide spread for a given B.O.D. removal, in p.p.m. Recently built plants appear to be more efficient in the use of air.

Neither the air used per pound of B.O.D. removed nor the pounds of B.O.D. applied to aeration tanks per 1,000 cu. ft. of air (Table VII) show any direct relationship to sewage strength. Air per pound of B.O.D. removed ranges from 500 cu. ft. at Milwaukee (new) up to 1,600 cu. ft. at Cleveland. (The 435 cu. ft. per pound

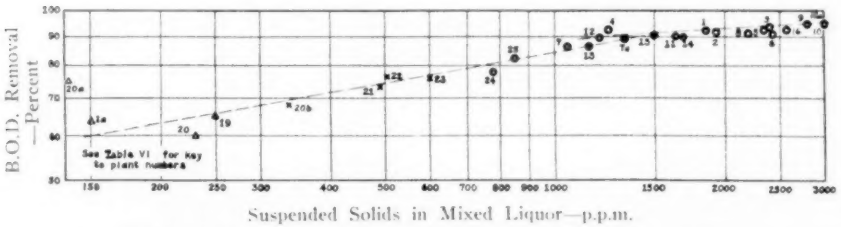


FIGURE 4.—Relation of mixed liquor solids and B.O.D. removal.

TABLE VI.—Comparison of B.O.D. Removals and Suspended Solids in Aeration Tanks

Plant[1]		Record		Sus. Sol. in Mixed Liquor (p.p.m.)	B.O.D. Removal[2] (%)
Location	No.	Date	Period		
Ann Arbor (Act. Sl.)	1	1947	1 yr.	1,850	92.3
Ann Arbor (Pl. Aer.)	1a	1945–46	8 mo.	150	63.2
Chicago So. West	2	1946	1 yr.	1,930	91.5
Chicago No. Side	3	1946	1 yr.	2,400	93.8
Cleveland	4	1945	7 mo.[3]	1,248	92.7
Decatur	5	1947	7 mo.[3]	2,342	92.5
Ft. Wayne	6	1941–45	5 yr.	2,420	91.0
Gary	7	1945	1 yr.	1,054	86.8
	7a	1941–45	5 yr.	1,325	89.6
Hammond	8	1942–46	5 yr.	2,196	91.5
Jackson	9	1942–46	5 yr.	2,801	94.9
Milwaukee West	10	1945	1 yr.	3,000	94.6
Milwaukee East	10a	1945	1 yr.	3,000	94.6
Peoria	11	1942–46	5 yr.	1,640	90.5
Pontiac	12	1946	1 yr.	1,200	90.0
San Antonio	13	1945–46	2 yr.	1,150	86.8
Springfield	14	1937–41	5 yr.	1,683	90.0
Two Rivers	15	1946	1 yr.	1,500	90.9
Indianapolis	16	1936–40	5 yr.	2,580	92.5
	19	....	....	250	65
Syracuse	18	....	10 wk.	68.5	62.3
	18	....	14 wk.	93	75.5
New York City					
Wards Island	20	....	28 wk.	230	60
	20a	....[4]	9 wk.	136	75
	20b	....[4]	40 wk.	338	68
Bowery Bay	17	1946–47	208 da.	1,680	89.5
	22	....	18 wk.	505	76.8
Jamaica	21	1944	16 wk.	490	73.3
	23	1945	1 yr.	600	76.2
Rockville Ctr., N. Y.	24	1936–40	5 yr.	780	78
Lake Charles, La.	25	1945	1 mo.	844	82.5

[1] See Table I.
[2] Based on settled sewage.
[3] Selected data, omitting months with operational disturbances.
[4] Experimental.

B.O.D. removed at Richmond must be increased for additional air obtained through gravity Vogt diffusion aerators.)

Possibly mechanical factors in the effectiveness of air diffusion plus air used for channel aeration, sludge air lifts, and excessive air losses, are more important than the relatively smaller quantity of air needed to supply the oxygen required for aerobic stabilization of organic matter.

Therefore, under the present situation of relatively low air use efficiency with reference to biological activity, there seems to be no advantage in attempting to include air quantities as an important closely related factor. Sufficient air must be provided to meet the oxygen requirements and to leave a dissolved oxygen residual of 1 or 2 p.p.m. The quantity to be supplied will depend on efficiency of air diffusion, which has not yet been fully developed. Data in Table VII and Figure 5 are rough guides to current plant design.

Character and Quantity of Returned Sludge

Two characteristics of activated sludge are important when it is re-

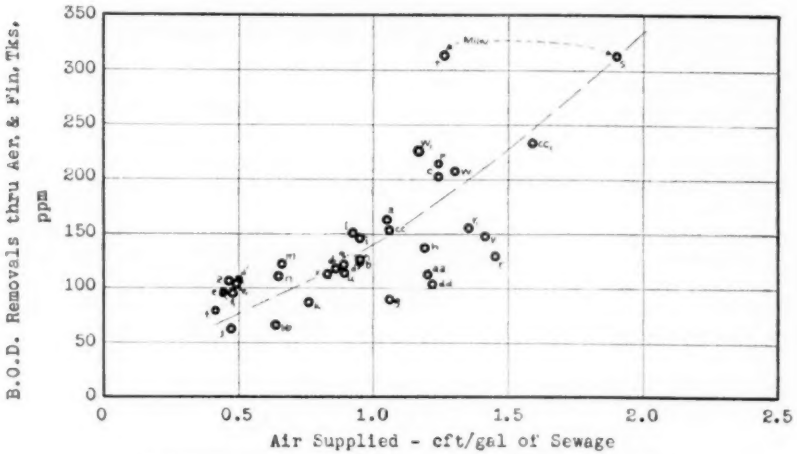


FIGURE 5.—Relation of air supplied and B.O.D. removal.

TABLE VII.—Air Quantities Compared to B.O.D. Applied and B.O.D. Removed

Plant	Date	Air Used (cu.ft.)		B.O.D. Applied (lb./1000 Cu.Ft. of Air)
		Per Gallon	Per lb. B.O.D. Rem.	
Ann Arbor	1944–46	1.05	770	1.45
	1947	0.92	703	1.54
	1945–46*	0.5	594	2.67
Austin	1944	0.95	897	1.32
Baltimore	1945	1.24	728	1.46
Chicago So. West	1946	0.86	876	1.25
Chicago No. Side	1946	0.49	645	1.65
Chicago Calumet	1946	0.48	677	1.63
Cleveland	1940–45	1.06	1,600	0.72
Decatur	1946	1.19	1,043	1.1
Fort Wayne	1941–45	0.95	773	1.41
Gary	1941–45	0.47	796	1.39
Hagerstown	1943–46	0.92	500	2.30
Hammond	1942–46	0.66	655	1.67
Jackson, Mich.	1942–46	0.65	690	1.53
Madison, Wis.	1947	1.23	690	1.88
Marion, Ind.	1942–45	0.89	886	1.24
Marshalltown	1943–46	1.45	1,245	1.02
Milwaukee West	1945	1.90	725	1.45
Milwaukee East	1945	1.26	481	2.20
Omaha	1946	1.04	1,210	1.03
Peoria	1942–46	1.30	745	1.49
Pontiac	1946	0.83	886	1.25
Richmond	1942–46	0.39	435	2.42
San Antonio	1945–46	1.2	1,277	0.90
Springfield	1942	0.64	1,120	1.00
	1937–41	0.70	710	1.56
Syracuse	1947	1.23	725	1.60
Two Rivers	1946	1.22	1,410	0.78

* Plain aeration, 8 months.

turned to the aeration tanks: (1) The sludge activity, including completeness of the biological stabilization of organic compounds; and (2) the sludge concentration (that is the suspended solids content), which determines the quantity to be returned in order to maintain a certain suspended solids concentration in the mixed liquor.

Most plant operators determine the sludge index and the solids concentration, but practically no information is available on sludge activity.

The usual ranges in activated sludge characteristics and quantities have been as follows:

Item	High	Low
Sludge index	395	43
Sludge solids (p.p.m.)	14,300	3,900
Per cent of sewage flow	55	15

The sludge volatile content also should be considered as an important factor, as this is the active portion of the sludge.

Efforts to find a mathematical or graphical relation between the activated sludge characteristics and quantities, as represented by present test data, have not uncovered any close relationship.

Extended sludge reaeration at Peoria and Decatur seems to have improved plant operation. Hatfield (13) has tried various combinations of using six aeration tanks, but seems to favor allotting a sufficient portion of the aeration tank volume to sludge reaeration to permit long reaeration periods.

Digested sludge and digester supernatant liquor have been used at Decatur and Peoria to increase the settling rate of the activated sludge. Witcher (14) modifies the plant operation to get a rapid settling sludge.

In the light of present understanding it appears desirable for a reasonably liberal flexibility to be provided in the plant design and then for the operator to use the aeration tank volume for sewage aeration or sludge reaeration as local experience finds desirable. Many existing plants have no provision for sludge reaeration or sludge concentration.

Temperature

Operating data averaged over periods as long as 1 or more years fail to show any changes in efficiency that appear to be definitely related to temperature. It is probable that this may be due to a masking of temperature effects by a multiplicity of other influences when averaged over such a long time period. Samuel (2) has found monthly averages of operating data relatively satisfactory.

The effect of temperature on biological life is relatively well known. The effect on oxygen requirements for biological stabilization of organic matter is not so well known. A number of laboratory researches have been made in efforts to determine temperature effects on various phases of the activated sludge process.

Sawyer and Rohlich (20) summarized an extended series of laboratory tests by the equation

$$y = 0.71x^{1.51},$$

in which y is relative activity in per cent of that at 25° C. and x is temperature in degrees Centigrade.

Samuel (2) in his study of monthly averages of plant operating data found that by application of the Sawyer-Rohlich equation to obtain equivalent contact aeration periods he could obtain reasonable correlation of several interrelated factors, whereas using computed aeration periods unadjusted for temperature gave plotted points that were merely a group of scattered points with no apparent interrelationship.

In order to determine a quantitative value for temperature effects more complete data will be needed. Operating data averaged over periods of possibly a week, or at least no longer than a month should be available for a larger number of plants. More com-

plete knowledge is also needed of the temperature factor in the biological stabilization of various organic compounds. Some laboratory research is in progress on the latter problem.

Summary

Operating results from 26 plants, averaged over periods from 1 to 6 yr., show that the activated sludge sewage treatment process can be expected to remove from 92.5 to 95 per cent of the B.O.D. and suspended solids from untreated domestic sewage in properly designed plants. Efficiency of the process is materially affected by a number of factors, of which sewage quantity variations and chemical characteristics of the sewage, due in part to industrial wastes, are major factors requiring a great deal more research before satisfactory methods may be devised to control their effects on plant efficiencies.

Limited progress has been made in delineating the general magnitude of the effect of certain factors, such as suspended solids concentration in the aeration tanks, air supply quantities, and aeration contact period. Determination must be made of the interrelation of several factors and the magnitude of other factors (such as temperature, nitrification, character of returned activated sludge with reference to biological activity, and the B.O.D. loading per unit of aeration tank volume) before final definition of the effect of various factors may be fixed.

More effective design and operation of primary sedimentation tanks would result in improved efficiency—many plant upsets which reduce the plant efficiency are due to insufficient capacity, inadequate hydraulic design of settling tanks, or the return of excessive quantities of waste activated sludge and digester supernatant liquor.

Further study of plant operating data is warranted, in conjunction with laboratory research, to determine the effect of certain important factors, such as temperature, chemical constituents of the untreated sewage, nitrification with reference to B.O.D. determinations, aeration contact time, and others.

To facilitate such study operating data, averaged over a week or a period not longer than a month, should be made available. Also, plant operators should make available more complete data on the chemical contents of the sewage, including at least the nitrogen in the influent as well as in the effluent of the plant, and should provide a true measure of the character of sewage entering the plant, including any sludge or supernatant liquor recycled through the primary tanks.

Improved laboratory techniques, particularly the B.O.D. technique now under extended study, to remove undesirable influences of double or multiple reactions in the test bottle during incubation, would materially help determination of interrelation of several factors.

Finally, this discussion has related to the simple parameter of percentage B.O.D. removals. Possibly a more complex parameter should be devised to more accurately establish the plant performance with reference to the several more influential factors.

References

1. Berberich, Joseph F., "B.O.D. Loadings as a Basis of Design for Activated Sludge Plants." An unpublished thesis, Mass. Inst. Tech.
2. Samuel, William L., "The Interrelation of Various Design Factors Related to B.O.D. Loading of Activated Sludge Plants." An unpublished thesis, Mass. Inst. Tech.
3. Stanley, Wm. E., and Berberich, J. F., "B.O.D. Loadings in Activated Sludge Plants." *Journal Boston Soc. C. E.*, **35**, 3, 236 (July, 1948).
4. Pearse, Langdon and Committee, "Report

of A.P.H.A. Committee on Sewage Disposal." THIS JOURNAL, **14**, 1, 3 (Jan., 1942).
5. National Research Council, "Sewage Treatment at Military Installations." THIS JOURNAL, **18**, 5, 791 (Sept., 1946).
6. Mann, Uhl T., "Plain Aeration of Sewage." THIS JOURNAL, **18**, 3, 459 (May, 1946).
7. Witcher, C. Preston, "Annual Reports for 1946 and 1947." Ann Arbor (Mich.) Sewage Treatment Plant.
8. Davis, Calvin V., "Handbook of Applied Hydraulics." McGraw-Hill Book Co., N. Y., p. 912.
9. Mohlman, F. W., "Nitrification." An editorial, THIS JOURNAL, **10**, 4, 792 (July, 1938).
10. Sawyer, C. N. and Bradney, L. B., "Modernization of the B.O.D. Test for Determining the Efficiency of Sewage Treatment Processes." THIS JOURNAL, **18**, 6, 1113 (Nov., 1946).
11. Hurwitz, E., Barnett, G. R., Beaudoin, R. E., and Kramer, H. P., "Nitrification and B.O.D." THIS JOURNAL, **19**, 6, 995 (Nov., 1947).
12. Kraus, L. S., Chemist , The Greater Peoria Sanitary and Sewage Disposal District, Peoria, Ill. Private Correspondence.
13. Hatfield, William D., Superintendent, Sanitary District of Decatur, Ill. Private Correspondence.
14. Witcher, C. Preston, Superintendent, Ann Arbor Sewage Treatment Plant, Ann Arbor, Mich. Private Correspondence.
15. Greeley, S. A., "The Development of the Activated Sludge Method of Sewage Treatment." THIS JOURNAL, **17**, 6, 1137 (Nov., 1945).
16. Torpey, Wilbur N., "Practical Results of Step Aeration." THIS JOURNAL, **20**, 5, 781 (Sept., 1948).
17. Greeley, S. A., "High Rate Biological Sewage Treatment." THIS JOURNAL, **15**, 6, 1069 (Nov., 1943).
18. Bloodgood, Don E., "Studies of Activated Sludge Oxidations at Indianapolis." THIS JOURNAL, **10**, 26 and 927 (1938).
19. Kraus, L. S., "Digested Sludge—An Aid to the Activated Sludge Process." THIS JOURNAL, **18**, 6, 1099 (Nov., 1946).
20. Sawyer, C. N., and Rohlich, G. A., "Activated Sludge Oxidations. IV. The Influence of Temperature Upon the Rate of Oxygen Utilization by Activated Sludges." THIS JOURNAL, **11**, 6, 946 (Nov., 1939).
21. Mann, Uhl T., "'Economized' Activated Sludge Tests Are Promising." *Sew. Wks. Eng.*, **16**, 514 (Oct., 1945).

FACTORS AFFECTING THE EFFICIENCY OF ACTIVATED SLUDGE PLANTS—A DISCUSSION

BY GAIL P. EDWARDS

Chief of Laboratories, Department of Public Works, City of New York, N. Y.

In his excellent paper Professor Stanley has made a comprehensive analysis of the many factors affecting efficiency in activated sludge sewage treatment plants. Only one of these factors—the loading factor—has been chosen for this discussion.

The rate of loading has been expressed in a number of ways. One is the ratio between the return sludge solids and the sewage solids entering the aerator; another is the pounds of B.O.D. added to or removed from each 1000 cu. ft. of aerator each day. Some of these loading factors are of interest in comparing plants, but are of little value in actual operation. Gould has suggested the term "sludge age" to represent the average number of days the sewage solids remain in the aeration system. It is calculated by dividing the weight of suspended solids in the aeration tanks by the weight of suspended solids added daily to the aeration tanks. This sludge age, which applies only when no sludge accumulates in the final tanks, is the reciprocal of the loading weight, expressed as pounds of suspended sewage solids added to the aeration system daily for each pound of activated sludge solids under aeration.

Gould believes that for activated sludge a sludge age of at least 3 days is necessary, and an age of 4 days is desirable. For high rate activated

sludge or modified sewage aeration, an age of 0.35 to 0.5 days seems satisfactory. Between conventional and high rate activated sludge there is an intermediate zone, in which very poor results are obtained. The sludge age in this zone may be 1 to 2 days. The advantage in the use of sludge age is that it is a working factor that can be changed readily by the operator. The age increases as the aeration tank solids increase. In the conventional activated sludge plant, the age can be varied somewhat by varying the solids concentration in the aerator. The amount of variation is restricted by the characteristics of the final tank system, which can care for only a limited amount of solids before the effluent becomes poor.

When the sludge age is 3 days or more the plant should function satisfactorily, but as the loading increases it soon becomes impossible to increase the solids in the aeration system to handle the load. Then the ratio of activated sludge solids under aeration to the entering sewage solids, and, therefore, the sludge age, becomes too low and the effluent deteriorates. It is possible to increase the capacity of an activated sludge plant by adding reaeration of sludge. This increases the aeration period of high concentrations of sludge, as well as the weight of solids under aeration and, by definition, the sludge age. However, ordinary reaeration is also limited in the range within which it can operate.

Gould (1) originated the idea of step aeration whereby the return sludge is added at the beginning of the aeration tank and the sewage is added at one or more points along the course of flow of the returned sludge. As the point of application of the sewage is shifted toward the effluent end of the tank, the length of the sewage contact period decreases and the sludge detention period increases.

Within limits, a gain can be effected in purification by increasing sludge detention at the expense of sewage aeration. There is the added advantage with step aeration that, as the points of sewage application are shifted toward the effluent end, fewer pounds of solids per day are added to the final tanks. Step aeration, therefore, permits great flexibility in operation by allowing wide variations in sludge age or in loading, and by lessening the rate of solids loading on the final tanks.

Where the activated sludge plant has sufficient capacity to handle the load, the use of step aeration does not necessarily improve the effluent. For example, with conventional aeration at the Tallmans Island plant (New York City), the average sludge age during 1946 was 5.2 days and the loading was 30 lb. B.O.D. per 1,000 cu. ft. of aeration tank capacity per day. For the year ending August 30, 1948, step aeration was used, the settled sewage being added in equal amount at points about ¼ and ¾ the distance through the aeration tank. The average sludge age was 8.2 days and the B.O.D. loading was slightly less than in 1946. In each case the effluents were about the same, although a better sludge index was obtained with step aeration. However, when loading becomes high, step aeration is an advantage. Torpey (2) has shown that at the Bowery Bay plant, B.O.D. loadings of 54 to 85 lb. of B.O.D. per 1,000 cu. ft. of aeration tank capacity per day were satisfactorily treated by step aeration in an aeration tank having a conventional detention period of 2.5 hours.

High loadings of B.O.D. and suspended solids can be handled efficiently by high rate activated sludge (modified sewage aeration) where a highly polished effluent is not required. The high rate activated sludge process consists essentially of the aeration of low concentrations of aeration solids for short periods. For the year ending August 30, 1948, the average detention

period in the aerator at the Jamaica plant was 2 hr. and the concentration of aerator solids was 650 p.p.m. The aeration tank receives screened raw sewage and, with a loading of 100 lb. of B.O.D. per 1,000 cu. ft. of aeration tank capacity, and with 353 cu. ft. of air per pound of B.O.D. removed, 83.7 per cent of the suspended solids and 77.5 per cent of the B.O.D. were removed. The effluents average 30 p.p.m. suspended solids and 41 p.p.m. B.O.D.; the excess sludge, 6.4 per cent solids, of which 74.1 per cent were volatile; and the sludge age, 0.37 days.

The use of step aeration and the concept of sludge age are important factors in improving the efficiency of the activated sludge process. Step aeration adds great flexibility to the handling of heavy organic loads and the determination of the sludge age permits a rapid analysis of one of the most important factors, loading.

References

1. Gould, R. H., "Tallmans Island Works Opens for the World's Fair." *Municipal Sanitation*, **10**, 185 (1939).
2. Torpey, W. N., "Practical Results of Step Aeration." THIS JOURNAL, **20**, 5, 781 (Sept., 1948).

ROSTER OF SANITARY AND PUBLIC HEALTH ENGINEERS

In cooperation with the National Security Resources Board, the American Public Health Association is preparing a roster of sanitary and public health engineer citizens of the United States. This roster, to a great extent, will supplement and bring up to date the roster prepared by the War Manpower Commission. Its uses will be manifold, but the immediate interest of the National Security Resources Board in such a roster is to provide a means by which trained sanitary and public health engineers can be assured of proper utilization of their professional training should another national emergency arise. The Engineering Section Project of the American Public Health Association is directly responsible for the collection of data and preparation of the roster.

The definition of a sanitary engineer prepared by the National Research Council in 1943 is being used as a basic description of individuals who should receive and complete the questionnaire. Judgment as to whether or not the individual meets the requirements of the definition will rest with each individual.

Files of the War Manpower Commission and a list of all engineers who served with the Sanitary Corps of the Army are being used as a basis for a mailing list in sending out the questionnaires. These two lists are being amplified by information obtained from membership lists of several of the national engineering societies, plus information submitted by state sanitary engineers through the cooperation of the Conference of State Sanitary Engineers, by larger consulting engineers, and by other individuals. Any engineer who does not receive a copy of the questionnaire within the next two or three months should notify the Engineering Section Project, American Public Health Association, 1790 Broadway, New York.

THE OXYGEN REQUIREMENTS OF ACTIVATED SLUDGE DETERMINED BY MANOMETRIC METHODS

By P. S. S. Dawson and S. H. Jenkins

Research Assistant and Chief Chemist, Birmingham, Tame and Rea District Drainage Board, England

At least three methods are available for measuring the biological activity of activated sludge: (1) the direct absorption of gaseous or dissolved oxygen, (2) the indirect method of measuring the drop in the oxygen demand of the sludge, and (3) the indirect method of following the carbon dioxide output of the sludge. The first method has been used by Grant, Hurwitz, and Mohlman (1); Sawyer and Nichols (2); and others. The second method has been less successful, probably because the B.O.D. test used to measure the oxygen demand is itself indeterminate. In the third method, as used by Heukelekian and Ingols (3) and Jenkins and Roberts (4), the assumption must be made that the rate of carbon dioxide output is the same as the rate of oxygen uptake.

In the direct absorption of oxygen by sewage and activated sludge, an advance in technique was made by Wooldridge and Standfast (5) by the use of Bareroft differential manometers. These authors did not refer to the use of Warburg manometers, but the application of such manometers to the measurement of the B.O.D. of sewage was recently described by Caldwell and Langelier (6).

Object of Present Investigation

Work was begun in this laboratory in 1944 to develop the use of microrespirometers in activated sludge studies, particularly as a means of following the effect of toxic substances on biological systems such as activated sludge. Difficulties in obtaining apparatus during the war restricted progress. Some preliminary work was carried out with Bareroft manometers loaned by the Water Pollution Research Laboratory. This work confirmed the need for replication of experiments, as recommended by Corbet and Wooldridge (7).

As standard apparatus was unobtainable, a thermostatically controlled tank was designed to take both Bareroft and Warburg manometers, which were attached to a backboard of standard dimensions. Spring steel clips screwed to the backboard were shaped so as to grip studs mounted on moveable frames close to either side of the tank. The two frames were connected by rods and a separate, moveable frame on one side of the tank was fixed at the top to the tank itself. The bottom part was attached to the manometer frames and to a moveable arm, so that when a reciprocating force was applied to the bottom part, the manometer frames swung to and fro, pivoted about the upper part of the swinging frame. One end of the moveable arm fitted into a slotted cam, which was driven through a series of pulleys from a ⅓-h.p. motor. By moving the arm along the slot the horizontal movement of the frame could be varied from 1 to 8 cm. Pulley wheels enabled the number of oscillations to be varied between 75 and 150 per min. The apparatus has given excellent service.

A thermoregulator giving control to 0.02° C. was connected to a 1.2-kw.

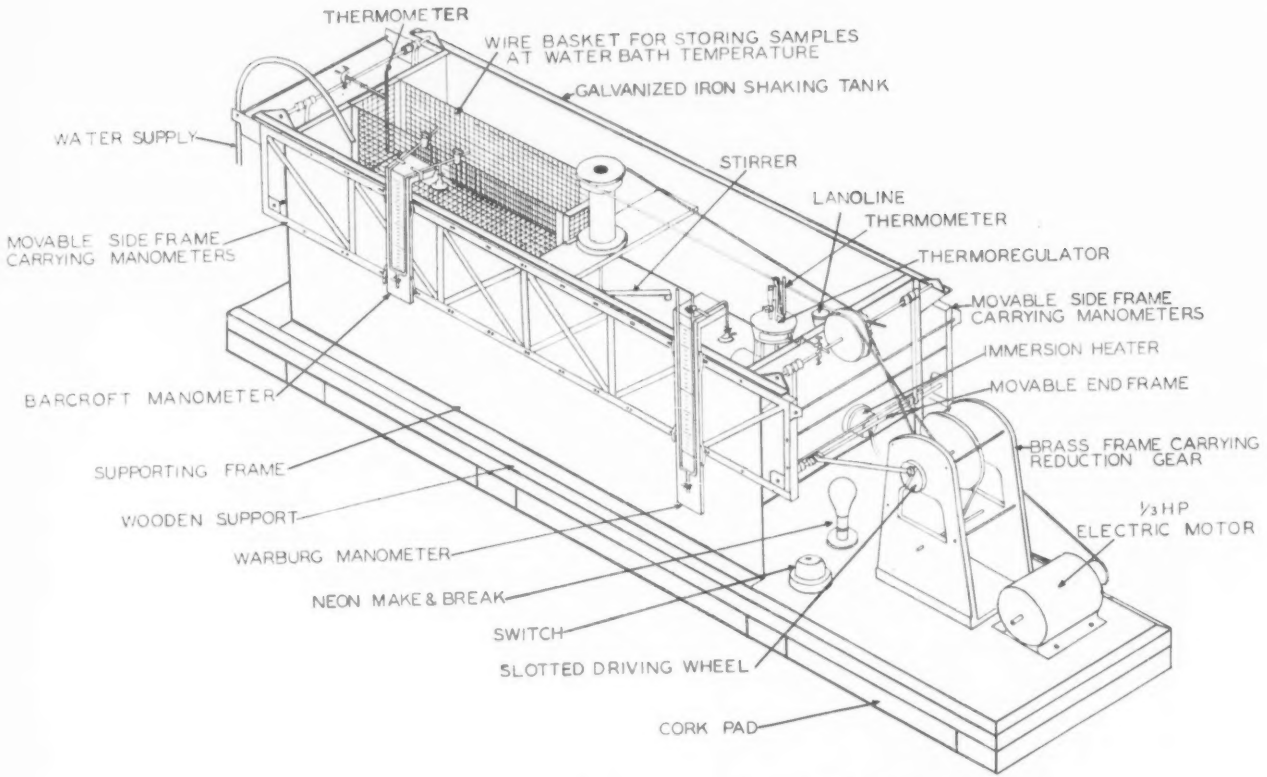


FIGURE 1.—Arrangement of tank for experiments with Barcroft and Warburg manometers.

immersion heater fitted into the side of the tank, underneath the thermometer. The stirring device in the tank was driven off the shaker motor. Temperature control was accurate to within at least 0.1° C. The tank and shaking gear are shown in Figure 1.

The manometer constants obtained by calculation (8) were checked by finding the volume of CO_2 evolved from known weights of sodium bicarbonate. Much calculation time was saved by the use of nomograms (9) for oxygen, carbon dioxide, and different volumes of reactants with Warburg and Barcroft monometers.

Colored kerosene was used as the gage fluid in the Barcroft manometers; Brodie solution (500 ml. water, 23 gm. sodium chloride, 5 gm. sodium tauroglycocholate, plus a few drops of alcoholic thymol and a few drops of methyl violet solution), in the Warburg manometers.

Uptake of Oxygen by Activated Sludge

In manometric experiments the uptake of oxygen must be independent of the shaking conditions. Preliminary experiments with buffered yeast suspensions and glucose, which have high rates of oxygen uptake, showed that a shaking rate of 130 oscillations per min. with a stroke of 3.5 cm. was adequate.

The activated sludge used in these experiments from Coleshill Works, which treats domestic sewage from 110,000 inhabitants. The sewage has a B.O.D. of 200 to 230 p.p.m. The activated sludge was used within 2 or

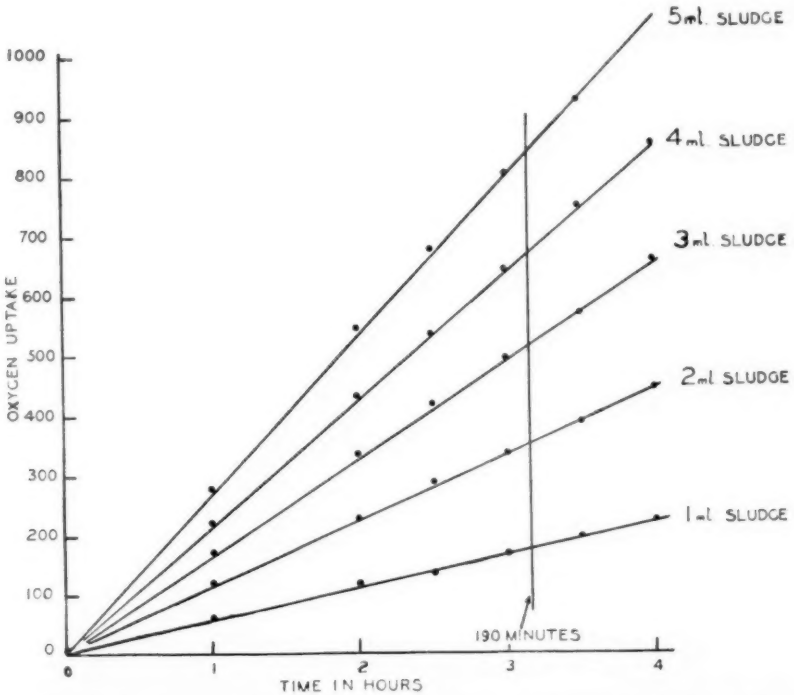


FIGURE 2.—Oxygen uptake, in micrograms, by various volumes of activated sludge.

3 hr. of its collection. Washed activated sludge containing 2,375 p.p.m. of suspended solids was added to duplicate Warburg flasks in 1-ml., 2-ml., 3-ml., 4-ml., and 5-ml. volumes, and the rate of oxygen uptake from air was determined at 28° C. The experiments were repeated on three successive days. Figure 2 shows the results of one test. Inasmuch as the rate of oxygen uptake does not decrease with increasing volumes of sludge, oxygen supply was not a limiting factor.

A plot of amount of oxygen taken up by the different volumes of sludge after 200 min. gave a straight line, showing that the oxygen uptake is strictly proportional to the volume of sludge used. This fact was established in 1930 by Grant, Hurwitz, and Mohlman (1).

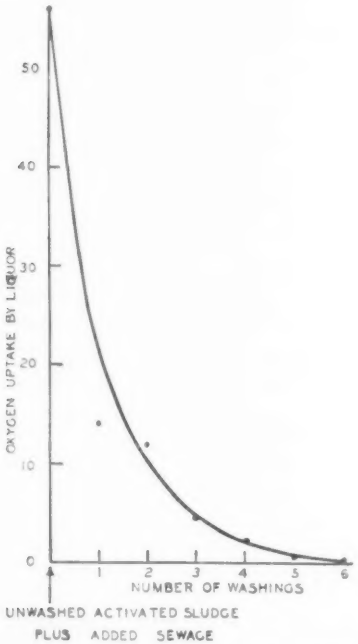


FIGURE 3.—Effect of successive washings on uptake of oxygen, in p.p.m., by activated sludge.

Throughout subsequent experiments the shaking rate was kept at 130 oscillations per min., and the length of stroke at 3 cm.

Error Involved in Manometric Method

Preliminary experiments showed that with yeast suspensions and glucose the agreement between the oxygen uptake in replicate determinations was excellent. Activated sludge was then used, washed and unwashed, buffered and unbuffered, in various degrees of replication. The results, when treated statistically as suggested by Corbet and Wooldridge (7), showed that an error of 4 to 5 per cent was obtained with manometers in duplicate or triplicate, less than this with more manometers, and that after 2 or 3 hr. aeration the errors were slightly smaller.

Oxygen Uptake of Washings from Activated Sludge

The liquid in contact with activated sludge may have an appreciable and by no means constant demand for oxygen. An example of the oxygen taken up by the washings from activated sludge after successive washings with water is shown by Figure 3. The activated sludge was first mixed with sewage. The liquor removable by centrifugation had an oxygen uptake of 56 p.p.m. The results showed that two washings reduced the oxygen uptake to 12 p.p.m., and four washings to a negligible figure.

Effect of Light

Light was excluded from four Warburg flasks by a wrapping of black cloth. To each of these and to four similar, unblacked flasks 4 ml. of thrice-washed activated sludge was added: 0.3 ml. of potassium hydroxide solution and filter paper rolls were placed in the inner cups. No buffer was added, the pH being 7.2 throughout the ex-

periment. Duplicate thermobarometers were used. The oxygen uptake at 28° C. was read at 30-min. intervals for 270 min.; the results obtained are shown in Figure 4, in parts by weight of oxygen per million parts by volume of sludge containing 1,000 p.p.m. suspended solids. These same units are used throughout this paper unless otherwise noted.

A slight but significant increase in oxygen uptake was found in the absence of light. In the flasks exposed to light a few *Euglena* were found. The explanation suggested to account for the increased oxygen uptake in the absence of light is that photosynthesis occurs in the presence of light. The oxygen thereby produced is available for oxidation purposes, so that a smaller volume of the oxygen originally present in the apparatus is used by the activated sludge. If this is the correct interpretation of the result, the difference between the two sets of average figures is a measure of the oxygen produced by photosynthesis under the conditions of the experiments.

Uptake of Oxygen from Atmospheres of Oxygen and Air, with and without Shaking

For this experiment, 4 ml. of thrice-washed activated sludge was added to 12 Warburg manometers containing 0.4 ml of potassium hydroxide. Six were filled with oxygen and six with air. Three of each set were kept stationary, three were shaken. The average of three determinations of the oxygen uptake in 5 hr. at 28° C. was as follows:

Atmosphere	Manometers Shaken	Manometers Stationary
Pure oxygen.....	33.6	29.4
Air.....	32.4	14.0

These values indicate that it is necessary to shake the manometers filled with air in order to obtain the same oxygen uptake as with pure oxygen. Even with an atmosphere of oxygen, failure to shake results in a reduced oxygen uptake.

Effect of pH

Several experiments were carried out to insure that the buffer solutions used

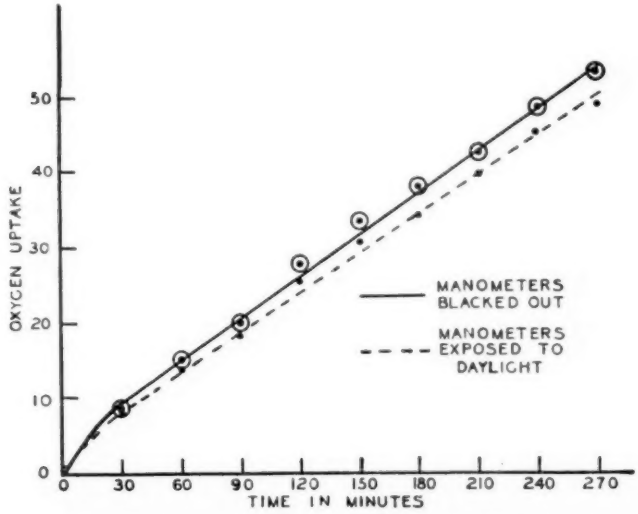


FIGURE 4.—Effect of light on uptake of oxygen.

to maintain selected pH values had no toxic or nutritional effect other than that due to the hydrogen ion concentration.

In order to allow for replication the pH range was covered in three separate experiments: pH 3 to 7, 6 to 10, and 9 to 13. In two subsequent experiments the full range was achieved using a single sample of activated sludge and one manometer for each pH value. The results of the first set of experiments, using different sludge samples for each of the pH ranges, gave the results shown in Table 2.

The pH range 4 to 13 was examined using the same sample of activated sludge. Duplication was obtained by repeating the experiment with the same sludge on two successive days. The results are shown in Figure 5.

The oxygen uptake of activated sludge between pH 7 and 8 was found at pH intervals of 0.2 using duplicate Warburg manometers and phosphate buffer. The average results of three consecutive experiments are shown in Figure 6.

These experiments show that washed activated sludge takes up oxygen over the pH range 4 to 13. The uptake below pH 5 and above 12 is negligible. The optimum range is between pH 7 and 8, with a maximum at about 7.4. From this point the activated sludge is less sensitive to increases in pH than to decreases. A drop in pH from 6 to 5 reduces the respiratory activity of the sludge by about 75 per cent. (It does not necessarily follow that the ability of the sludge to cause flocculation is affected in the same way.)

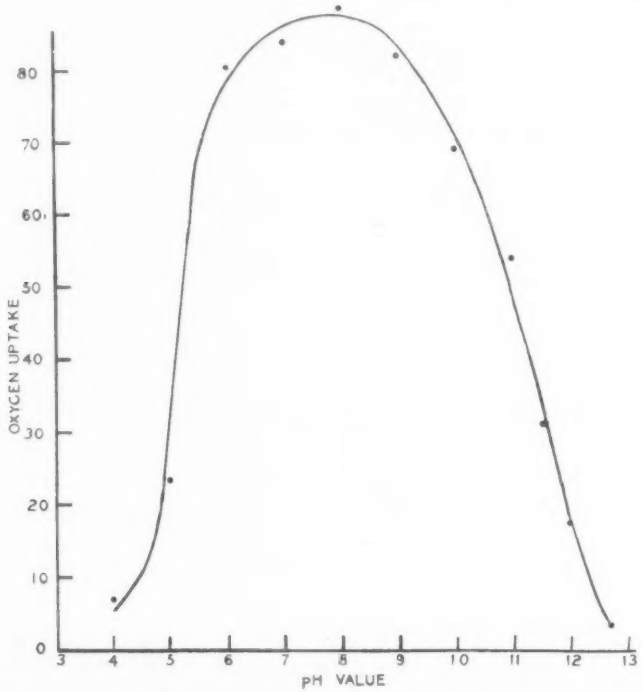


FIGURE 5.—Oxygen uptake of activated sludge at different pH values.

TABLE 2.—Oxygen Uptake[1] by Activated Sludge Buffered at Different pH Values

pH Range	Buffer Used[2]	Actual pH Value	Oxygen Uptake[3]
3 to 7	Phthalate–NaOH	3.4	4.0
	Phthalate–NaOH	4.6	13.9
	Phthalate–NaOH	5.3	19.5
	KH_2PO_4–NaOH	6.3	41.5
	KH_2PO_4–NaOH	7.0	49.1
6 to 10	KH_2PO_4–NaOH	6.0	73.0
	KH_2PO_4–NaOH	7.0	79.9
	KH_2PO_4–NaOH	8.0	81.7
	H_3BO_3–KCl–NaOH	8.0	78.2
	H_3BO_3–KCl–NaOH	9.0	74.7
	H_3BO_3–KCl–NaOH	10.0	69.4
9 to 13	Glycocoll-NaCl-NaOH	9.1	36.5
	Glycocoll-NaCl-NaOH	9.9	26.9
	Glycocoll-NaCl-NaOH	11.0	21.4
	Glycocoll-NaCl-NaOH	12.0	9.4
	Glycocoll-NaCl-NaOH	12.7	2.7

[1] As parts by weight of oxygen per million parts by volume of sludge containing 1,000 p.p.m suspended solids.
[2] Made according to formulas in Clark (10).
[3] Average of duplicate determinations.

The results given above agree substantially with those of Wooldridge and Standfast (5) except that the authors found that activated sludge will respire over a slightly wider range of pH values. However, different sludges were used. The differences in behavior of activated sludge obtained from different plants have not yet been examined.

Effect of Temperature

The rate of oxygen uptake was examined at various temperatures between 0° and 48° C.: namely 0° (± 0°); 12° (± 0.4°); 18° (± 0.2°); 22° (± 0.2°); 28° (± 0°); 38° (± 0.1°); 44° (± 0.2°), and 48° (± 0.2°). The determinations were made in triplicate, with a fourth manometer as a thermobarometer, and were carried out in groups as follows: (a) 0°, 12°, 18°, 22°; (b) 18°, 22°, 28°, 38°; (c) 28°, 38°, 44°, 48°; (d) 18°, 28°, 38°, 48°. The various baths

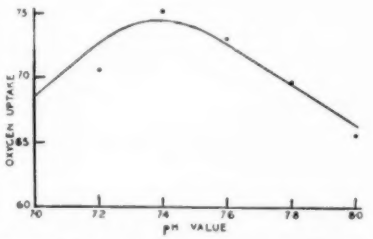


FIGURE 6.—Oxygen uptake of activated sludge in the optimum pH range.

used were not fitted with shaking apparatus and the manometers were therefore shaken by hand whenever possible.

The suspended solids were determined in each batch of activated sludge used and the oxygen uptakes calculated to the same suspended solids content. Figure 7 gives the results obtained.

The rate of oxygen uptake during the first few hours at five different temperatures is shown in Fig. 8. Up to 28° C. the relationship between time and uptake is a straight line, but at 37° and 48° there is a marked falling off in the uptake rate within the first hour of aeration. This is probably due to the inactivation of organisms or specific enzime systems. An increase in oxygen uptake by activated sludge between 15° and 25° C. was noted by Sawyer and Nichols (2).

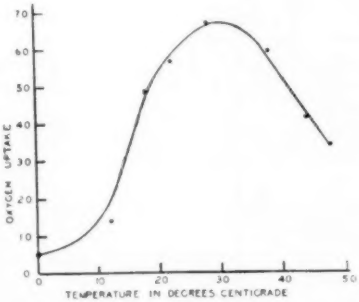


FIGURE 7.—Relationship between temperature and oxygen uptake of activated sludge.

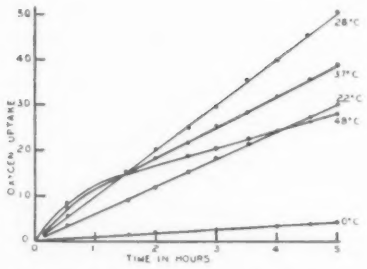


FIGURE 8.—Oxygen uptake during the first 5 hr. by activated sludge at various temperatures.

Effect of Oxidation—Reduction Potential

The apparatus used for this experiment consisted of a 120 ml. jar fitted with a rubber bung carrying a glass electrode, a platinum electrode, and a standard calomel half cell, connected to a pH electrometer which gave readings in pH units or millivolts. A single jar was used; measurements of oxygen uptake were made simultaneously on the same sample of activated sludge in Warburg manometers. The electrodes and standard cell were cleaned in nitric acid and then in distilled water before use.

Buffered sludge was added to the jar and the pH determined with the glass electrode in circuit. With the platinum electrode in circuit the potential E_h was read off at intervals. Readings of oxygen uptake were also read in parallel manometers. At the end of each experiment the pH of the sludge was again determined.

Effect of Aeration.—Washed activated sludge, buffered at pH 7.4, was shaken in the jar and in manometers. After 80 min., shaking was stopped in order to allow conditions to become anaerobic. The results, plotted in Figure 9, show that a fall in the rate

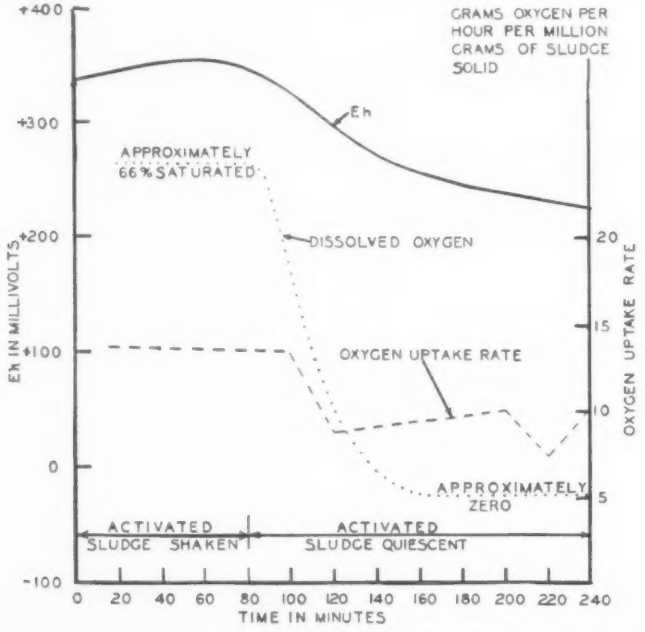


FIGURE 9.—Relationship between E_h and oxygen uptake of activated sludge.

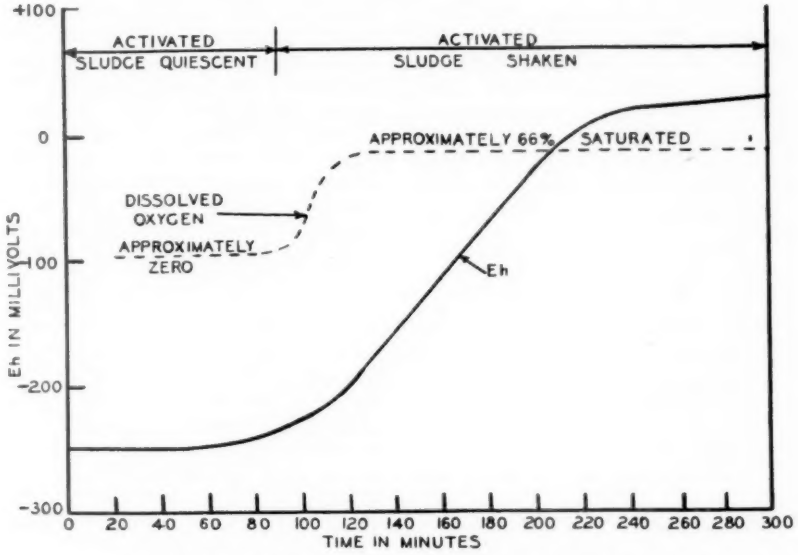


FIGURE 10.—Effect of aeration on E_h of stale activated sludge.

of oxygen uptake (in p.p.m. per hr.) corresponds with a drop in the dissolved oxygen concentration and in the potential.

Effect of Stagnation.—The conditions of the previous experiment were reversed. A charge of sludge was kept stagnant for 2 days. After measuring its E_h and oxygen uptake for 90 min., the sludge was shaken in air. The results, given in Figure 10, show that whereas the E_h potential took 150 min. to reach its maximum value, the oxygen uptake maximum was reached in 30 min. This difference is probably due to the two types of apparatus used for E_h and oxygen uptake measurements.

Intermittent Shaking.—Fresh activated sludge was shaken and then allowed to stagnate, this procedure being repeated several times. After 7 hr. the sludge was kept anaerobically overnight and then re-shaken. The results of E_h determinations, as given in Figure 11, show that the fluctuation from aerobic to anaerobic conditions causes increases and decreases in the oxidation-reduction potential. The longer the sludge is kept under anaerobic conditions, the greater is the potential difference.

The oxygen uptake rate varies with the change in E_h, but the experiments described do not justify anything more than qualitative conclusions being drawn. The authors' results confirm the relationship between the dissolved oxygen content and the E_h value of activated sludge, established by Moore and Ruchhoft (11) and Rohlich (12). The manometric measurements show that the E_h value is followed more closely by the rate of oxygen uptake by the activated sludge than by the dissolved oxygen curve. Presumably, once a minimum dissolved oxygen concentration is reached, which Rohlich (12) puts at about 1 p.p.m., the dissolved oxygen concentration ceases to be a factor of importance capable of limiting the rate of oxygen uptake.

The E_h value of fresh activated sludge was found to be 300 millivolts.

When kept anaerobically, this figure fell to − 210 millivolts after 1 day, − 290 millivolts after 2 days, and − 310 millivolts after 10 days. These values suggest that the conditions were anaerobic within a few hours. Under such conditions the initial oxygen uptake might be partly due to the chemical oxidation of easily oxidizable substances.

Effect of Staleness

Plant operators are familiar with the deterioration in effluent resulting from the use of activated sludge that has become stale through a shortage of air or through over-detention in tanks. The effect of staleness on the oxidizing power of activated sludge was studied by completely filling 250-ml. bottles with one sample of fresh, unwashed activated sludge. The contents were examined at intervals, using the following procedure:

100 ml. of the shaken sample was centrifuged and the supernatant liquor decanted. The residual sludge was washed three times with water and then made to 100 ml. The untreated sludge sample was also examined. The oxygen uptake from air of 4 ml. each of untreated sludge, washed residual sludge, and supernatant liquor was found in duplicate Warburg manometers over a period of several hours, taking ½-hr. readings. A plot of the results obtained after 4 hr. is shown in Figure 12.

The oxygen taken up by the sludge before washing does not necessarily equal the uptake of the washed sludge plus that of the liquor for the reasons that: (1) soluble and colloidal oxygen absorbing material is removed from the sludge by washing and most of this is lost; (2) the suspended solid content of the sludge is lowered by about 15 per cent in the washing process, which reduces the oxygen demand correspondingly; and (3) hydrogen sulfide and sulfides, which were present after the third day, are oxidized with great rapidity and were probably

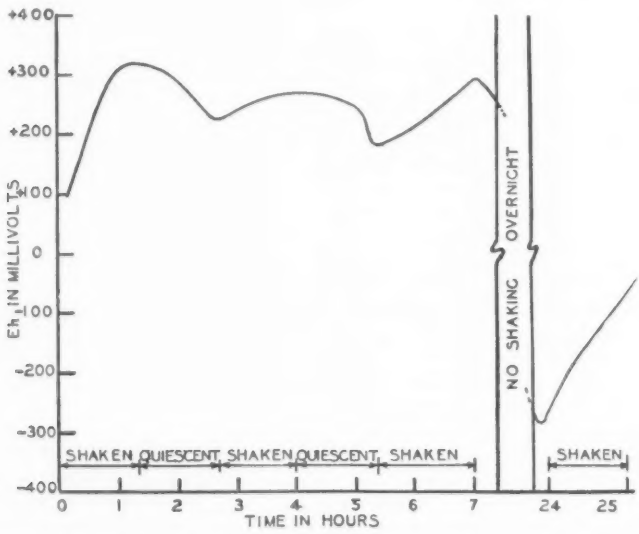


FIGURE 11.—Changes in E_h of activated sludge kept alternately aerobically and anaerobically.

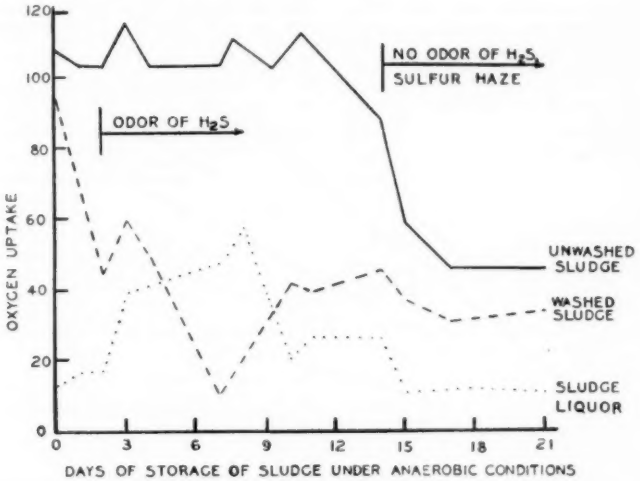


FIGURE 12.—Effect of keeping activated sludge anaerobically on the oxygen uptake of the sludge, washed and unwashed, and of the sludge liquor.

partly oxidized by atmospheric oxygen during manipulation.

The results show that the total oxygen uptake remained fairly uniform for about 10 days and then declined rapidly. The washed sludge uptake fell sharply from the commencement to 88 per cent of its original value. This fall coincided with a change in the staining reactions of the organisms from Gram negative to Gram positive. The reduction in oxygen uptake by the washed sludge might have been due either to the decomposition and removal of oxidizable material on washing, or to the death of aerobic organisms. The former cause is the more probable.

The oxygen uptake of the sludge liquor rose during the first 7 days. This suggests that substances having a demand for oxygen in the solid phase of the fresh sludge decomposed, yielding sulfide, and thereby reduced the oxygen demand of the solid sludge at the expense of the sludge liquor.

The reduction of the unwashed sludge oxygen uptake coincided with the formation of sulfur, the presence of which was confirmed by extraction with carbon bisulfide. The oxygen uptake of the sludge liquor also fell. This was probably the result of flocculation of oxidizable matter, in addition to the removal of sulfide, inasmuch as the oxygen uptake of the washed sludge showed a marked increase after the seventh day of keeping.

Relationship Between Activated Sludge Concentration and Oxygen Uptake

Washed activated sludge was thickened and then made up to give suspended solids concentrations of 500, 1,000, 1,500, 2,000, 2,500, and 3,000 p.p.m. The oxygen taken up from air by 4-ml. duplicate portions of each concentration was found in Warburg manometers. The uptakes at 40-min. intervals, up to 240 min., are given in Figure 13, which shows that the oxygen uptake was proportional to the sludge concentration.

A further experiment was carried out with a range of sludge concentrations extended far beyond that possible in actual practice; specifically, 2,500, 5,000, 7,500, 10,000, 12,500, and 15,000

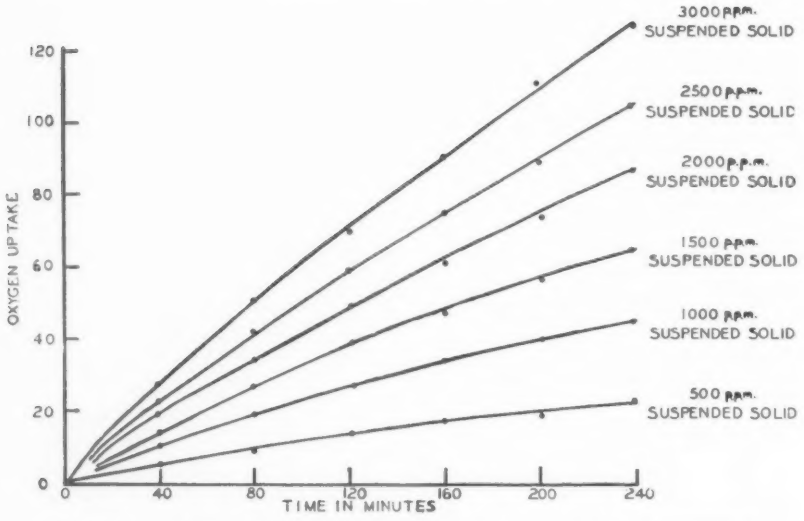


FIGURE 13.—Oxygen uptake by activated sludge containing various amounts of suspended solids.

p.p.m. of suspended solids. At 12,500 p.p.m. the sludge began to lose its liquid mobility. The experiment was made in Warburg manometers filled with air. When it was repeated, additional manometers were used to determine the oxygen uptake from an atmosphere of pure oxygen for the three highest sludge concentrations.

The relationship between the oxygen taken up after 90 min. and the sludge concentration is shown in Figure 14.

At a suspended solids concentration of 12,500 p.p.m.—the point where the sludge no longer flows freely, and does not break up so readily on shaking—the uptake of oxygen from air begins to fall off. With pure oxygen in the

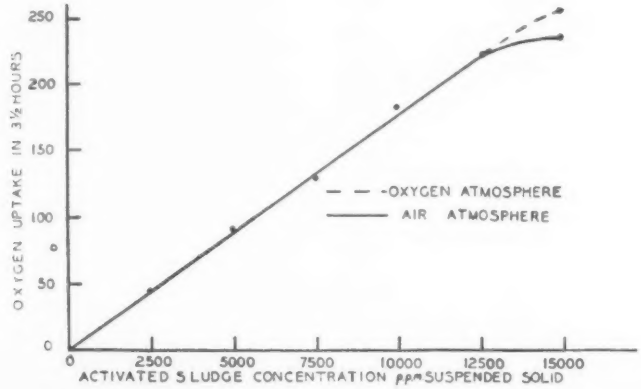


FIGURE 14.—Effect of sludge concentration on oxygen uptake.

manometers the rate of oxygen uptake falls off in the same region, although not to the same extent as with air. The inference is that the limiting factor affecting the oxygen uptake at the higher sludge concentrations is not the oxygen supply, but the rate at which the oxygen diffuses through the viscous sludge.

Sterilized Activated Sludge

The oxygen taken up in 3 hr. by fresh activated sludge (at 1,000 p.p.m. suspended solids) was determined before and after filtration through Seitz filters. The comparative values were 70.6 and 73.3, respectively. The supernatant liquor from the fresh sludge was also Seitz filtered, the oxygen uptake measured before filtration being 2.8; that after filtration was 0.8. These results bring out the well known fact that practically the whole of the oxygen uptake resides in the solid fraction of the activated sludge.

The oxygen uptake in 3 hr. of a sample of activated sludge before and after sterilization by heat gave comparative duplicate results of 108.2 and 111.3 for the unsterilized condition and 1.1 and 0 for the sterilized condition, proving that micro-organisms were almost completely responsible for the oxygen uptake.

Because the micro-organisms responsible for the oxygen uptake are associated in clumps, an attempt was made to test the theory that an increase in the rate of oxygen uptake would result if the surface of the sludge, and therefore the surface of organisms, was increased. This was done by homogenizing the sludge, which Allen (13) has found to cause a 10- or even 100-fold increase in the bacterial count of activated sludge.

Washed activated sludge was divided into two portions. One portion was homogenized six times and 2.5 ml. of charges of the two lots of sludge were added to triplicate manometers. The oxygen uptake from air was measured with the manometers stationary in order to delay re-flocculation of the homogenized sample. After 2 hr. the manometers were re-set at 0 and the oxygen uptake determined for a further 2 hr., observing the normal shaking conditions. Comparative results were as follows:

For the unhomogenized sludge—not shaken, 35.4; shaken, 63.0:
For the homogenized sludge—not shaken, 63.0; shaken, 69.7.

The results show that dispersal of the activated sludge causes a marked increase in oxygen uptake under quiescent conditions. One inference to be drawn from this observation is that a badly flocculated activated sludge would absorb oxygen from its liquor at a greater rate during settlement than would well flocculated sludge. The results also indicate that the effect of homogenization in increasing the rate of oxygen uptake persists even when the activated sludge is re-flocculated by shaking.

The effect of homogenization might be due to the amount of active surface being increased, or to a speedup in the diffusion of oxygen through the sludge to the organisms. An attempt to test the validity of these views was made by adding various inert substances to 4-ml. portions of washed activated sludge in duplicate Warburg manometers. The results shown in Figure 15, were inconclusive. Several substances hardly affected the oxygen uptake, although pumice and asbestos gave a marked increase. In general, there was little relationship between the oxygen uptake and the amount of inert substance added. Quite different views have been expressed—for example, by such investigators as Theriault (14), Whitehead and O'Shaughnessy (15), and Ziegerli (16)—concerning the effect of inert substances on the efficiency of treatment by activated sludge. However, the evidence in favor of any one view is not convincing.

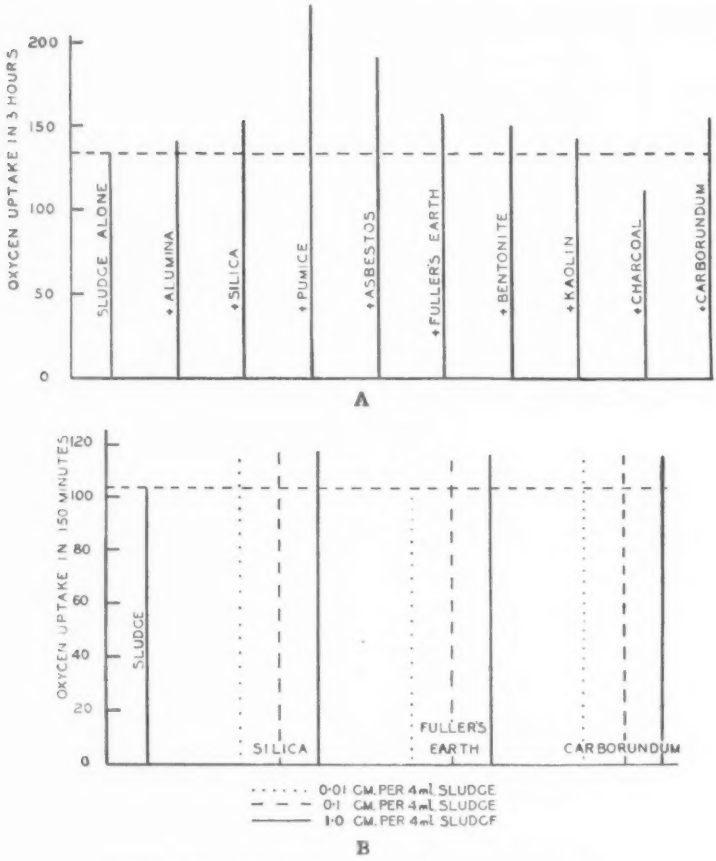


FIGURE 15.—Effect of inert materials on oxygen uptake.

Summary and Conclusions

The conclusions drawn from the experiments described herein may be summarized as follows:

1. The oxygen taken up by washed activated sludge was proportional to the amount of sludge involved. A straight-line relationship was also found between the time of aeration and the oxygen used.

2. Using washed activated sludge, the error involved in measuring the oxygen uptake with duplicate or triplicate manometers is 4 to 5 per cent.

3. The liquor in contact with activated sludge has an appreciable demand for oxygen. Washing the sludge twice with water reduces this demand to a negligible amount.

4. Under the authors' conditions of experiment, a slight but significant effect was detected due to photosynthesis. The result was that aeration flasks exposed to light took up less oxygen from the surrounding atmosphere of air because an additional quantity of oxygen was produced by photosynthesis.

5. Oxygen was absorbed from air

quicker in manometers that were shaken than in those that were stationary. The difference still persisted, but was less marked, from an atmosphere of pure oxygen.

6. Below pH 5 and above pH 12 the oxygen uptake is very small. The optimum range is between pH 7 and 8, with an optimum at about 7.4. Increases in pH from this point affect the oxygen uptake less than do corresponding decreases. A pH drop from 6 to 5 reduces respiratory activity by about 75 per cent. The effect of pH on flocculation was not examined in this work.

7. As a result of experiments ranging from 0° to 48° C., the authors conclude that the optimum temperature for oxidation by activated sludge is about 28° C. At this temperature the oxidation is three times as rapid as at 12° C.

8. The relationship between the oxidation-reduction potential, E_h, of activated sludge kept under aerobic and anaerobic conditions, and the oxygen uptake of the sludge, was determined manometrically. The oxygen uptake was high when the sludge was kept aerobically, and low under anaerobic conditions. The E_h curve followed the oxygen uptake curve more closely than the curve for dissolved oxygen. This suggested that above a certain minimum concentration, dissolved oxygen had little effect on the rate of oxygen uptake by activated sludge.

9. Under anaerobic conditions the total amount of oxygen required for respiration remained constant for several days. During that period the oxygen demand of the solid decreased and the demand of the liquid increased. With prolonged storage under anaerobic conditions, the total oxygen demand of activated sludge decreased. The oxygen demand of the liquid portion also decreased, due to the conversion of sulfides into sulfur.

10. The oxygen taken up by activated sludge was proportional to the amount of solid matter present. With very high concentrations of solids—12,500 p.p.m. and over—the rate of oxygen uptake decreased when air was present in the manometers because the oxygen could not diffuse through the sludge quickly enough to meet the oxygen demand. Even in the presence of pure oxygen a slight falling off in oxygen uptake was noted. This only occurred with concentrations of sludge beyond those normally employed in actual practice.

11. By using Seitz filters and heat sterilization, practically all the oxygen demand was found to reside within the solid portion of activated sludge and to be biological in origin. From an atmosphere of air under quiescent conditions activated sludge dispersed by homogenization had a greater oxygen uptake rate than flocculated sludge. This greater uptake rate still persisted when homogenized sludge was shaken. The addition of inert substances, which might increase the surface of the activated sludge, had no appreciable effect in some cases in increasing the oxygen uptake. In two cases an increase was observed. The authors were unable to arrive at any conclusion regarding the effect of inert substances on the respiratory activity of activated sludge.

Acknowledgment

This work was carried out in the laboratory of the Birmingham, Tame and Rea District Drainage Board, and is published by permission of Mr. F. C. Vokes, Engineer to the Board.

References

1. Grant, S., Hurwitz, E., and Mohlman, F. W., "The Oxygen Requirements of the Activated Sludge Process." THIS JOURNAL, **2**, 228 (1930).
2. Sawyer, C. N., and Nichols, M. S., "Activated Sludge Oxidations. 1. Effect of Sludge Concentration and Temperature upon Oxygen Utilization." THIS JOURNAL, **11**, 51 (1939).
3. Heukelekian, H., and Ingols, R. S., "Stud-

ies on the Clarification of Activated Sludge. III. Carbon Dioxide Production during the Clarification and Oxidation Stages of Activated Sludge." THIS JOURNAL, **9**, 717 (1937).

4. Jenkins, S. H., and Roberts, S. J., "Studies on Activated Sludge. I. The Flocculation and Oxidation of Sewage Solids by Activated Sludge." *Jour. Soc. Chem. Ind.*, **58**, 225 (1939).
5. Wooldridge, W. R., and Standfast, A. F. B., "The Use of the Barcroft Differential Manometer in the Estimation of the Oxygen Absorption of Sewage." *Biochem. Jour.*, **30**, (1), 141 (1936).
6. Caldwell, D. H., and Langelier, W. F., "Manometric Measurement of the Biochemical Oxygen Demand of Sewage." THIS JOURNAL, **20**, 202 (1948).
7. Corbet, A. S., and Wooldridge, W. R., "An Investigation of the Accuracy of the Barcroft Differential Manometer in Respiration Studies." *Biochem. Jour.*, **30**, (1), 132 (1936).
8. Dixon, M., "Manometric Methods." Cambridge University Press, Second Edition, p. 14 (1943).
9. Dixon, M., "Nomograms for Manometer Constants." Cambridge University Press, reprinted from *Biochem. Jour.*, **39**, 427 (1945).
10. Clark, W. M., "The Determination of Hydrogen Ions." Balliere, Tindall, and Cox, London.
11. Moore, W. A., and Ruchhoft, C. C., "Oxidation-Reduction Studies. II. Oxidation-Reduction Potentials Developed in Sewage and Sewage-Activated Sludge Mixtures." THIS JOURNAL, **15**, 880 (1943).
12. Rohlich, G. A., "Oxidation-Reduction Potential Measurements in Activated Sludge and Activated Sludge-Sewage Mixtures." THIS JOURNAL, **16**, 540 (1944).
13. Allen, L. A., "The Bacteriology of Activated Sludge." *Journal of Hygiene*, Cambridge, **43**, 424 (1944).
14. Theriault, E. J., "A Biozeolitic Theory of Sewage Purification." *Jour. Ind. and Eng. Chem.*, **28**, 83 (1936).
15. Whitehead, H. C., and O'Shaughnessy, F. R., "Improving the Efficiency of Activated Sludge." *Surveyor and Municipal and County Engineer*, March 13, 1936.
16. Ziergerli, P., *Ges. Ing.*, **60**, 499 (1937), and THIS JOURNAL, **10**, 181 (1938).

BIBLIOGRAPHY ON REFUSE COLLECTION AND DISPOSAL

An extensive bibliography in the field of refuse collection and disposal is now available, according to an announcement of the U. S. Public Health Service. This is said to be the first such comprehensive bibliography.

The bibliography contains references to material published during the years 1940–48, and is based on a review of 12 indexes, readers guides, and services. The references are arranged alphabetically by author. Abstracts of the articles are not included.

The 66-page publication, compiled by Leo Weaver, of the Division of Sanitation, contains close to 1,000 entries from U. S. and British and other foreign professional journals and periodicals, on such subjects as street cleaning, garbage collection and incineration, garbage disposal with sewage (kitchen sink grinders), feeding of garbage to hogs, and operation of sanitary land-fills.

A copy of the bibliography, "Refuse Collection and Disposal," may be obtained on request from the Surgeon General, U. S. Public Health Service, attention of Division of Sanitation, Washington 25, D. C.

BIOLOGY OF SEWAGE TREATMENT *

By James B. Lackey

The Blakiston Company, Philadelphia, Pa.

Almost all complete treatment of sewage is inevitably a biological treatment. First of all, sewage treatment is a degradation of complex organic matter—proteins, carbohydrates, and lipids—to less complex compounds, the ultimate goal being the production of methane, carbon dioxide, hydrogen sulfide, and salts, especially nitrates. In actual practice, decomposition of the putrescible matter usually is not carried quite to this ultimate in sewage treatment plants for economic reasons.

Secondly, few methods of treatment produce an environment unsuitable to some form of life. The various anaerobic methods are favorable to an enormous development of bacteria, fungi, and less well known organisms. Aerobic methods not only produce large numbers of the same organisms, but in addition produce protozoa, rotifers, worms, some lesser known groups and, often, crustacea, insects, and snails. Combinations of aerobic and anaerobic methods, as in digestion followed by contact aeration, expose the sewage to two types of organisms and seem to offer the best possibility of complete degradation, especially needful in the case of sulfur compounds. However, the steps apparently should be successive and not combined. Thus, in high rate filters and Hays process treatment plants a partial anaerobiasis sometimes obtains, and digestion and oxidation are none too successful. If the sewage is treated with heat, chlorine, or other chemicals, the biological action is usually only delayed or long drawn out, for such treatment does not destroy the putrescible matter in sewage, but only stops biological action temporarily. Hall (1), for example, stated that chlorine did not oxidize a sewage effluent sufficiently to prevent its becoming a nuisance later, because the chlorinated material stimulated a very heavy algal growth in the receiving stream. It must be remembered, however, that nitrates, sulphates, phosphates, and other such salts are a preferred form of fertilizer for green plants.

The importance of this biologic action has long been known, but specific details concerning it are so frequently asked that a summation of existing knowledge and the direction of future investigation seems to be in order. A list of the papers on biologic aspects of treatment from 1920 on would be very long, but this biologic phase of the work still suffers from a lack of concerted and correlated attack.

Anaerobic Biology

What of the biology of anaerobic treatment? All anaerobic treatment seems to have substantially the same biologic features. This is due to (1) a lack of oxygen; (2) the presence of at least some hydrogen sulfide; and (3) relatively uniform conditions of temperature, light, etc. It seems to be generally assumed that most digestion of this type is carried out by bacteria, and direct examination reveals no macroscopic life, although in anaerobic streams, storage lagoons, and such situations occasional worms and insect larvae occur. The visibly active inhabitants are generally bacteria, together with about 18 species of protozoa di-

* Presented at the Twenty-first Annual Meeting, Federation of Sewage Works Associations; Detroit, Mich.; Oct. 18–21, 1948.

vided almost equally among flagellates, ciliates, and amoebae. None of these generally are present in large numbers, and often the protozoa are extremely scarce, thus practically precluding any large role for protozoa in normal anaerobic digestion.

With regard to the bacteria and fungi, the earliest studies first provided surveys. As an example of such surveys might be mentioned the early survey of Gaub (2) at New Brunswick, and the papers of Hotchkiss (3, 4, 5) and Heukelekian *et al.* (6, 7, 8). There are many other excellent papers on the bacteriology of sewage treatment, but the papers cited above represent survey work; and survey work is basic to any true evaluation of types and functions of organisms accomplishing purification. Some of these surveys, and some subsequent ones, extended to types or to groups of bacteria and not to the identification of species, or even genera, nor did they give population densities. Sometimes relative densities of certain forms were shown, but today there is no comprehensive listing of genera and species, together with ratios of expectancy, for Imhoff, septic tank, separate sludge, or any type of anaerobic treatment.

There is better information as to function and environmental occurrence. Thus, we are well informed about cellulose digesters, methane producers, thermophilic bacteria, hydrogen sulfide tolerant bacteria, etc., as groups. There is also much information about the action of species, genera, or groups on sewage, and about the survival or development of bacteria in sewage. These are largely laboratory experiments, necessary and of great value. For anaerobes, the methane bacteria studies of Heukelekian and Heinemann (9) represent almost the only specialized information comparable to the work of Butterfield and Wattie (10, 11, 12) on the aerobic zooglea.

Direct microscopic examination of anaerobic sewage solids under digestion, using diameters of approximately 100X, 440X, or 1600X, fails to show excessively large numbers of motile bacteria. Large counts are obtained, as might be expected, by culture methods; but such methods still give a very incomplete picture of the numbers of bacteria carrying on the process of digestion. Better comprehension of the process would be possible if the kinds and numbers of bacteria actually at work were known.

Because the active number of such bacteria seems low on direct examination, yeasts, filamentous fungi, and actinomycetes may be looked for. Here again, a disappointing quantity of visibly viable forms is encountered; cultural examination for such forms that might be actively digesting anaerobic sewage solids has been sadly neglected.

Actually, then, it appears that virtually no animal life is known to be a part of anaerobic sewage digestion; that such digestion is assumed to be largely a bacteriologic process, but that too little is known of the species and numbers of bacteria doing this work; and that the yeasts and other fungi possibly concerned are very little known. There is here a fertile field of investigation for a mycologist.

The protozoa of anaerobic sewage are fairly well known (13, 14), except for those which occur sporadically. It should be noted that the writer has never found any of them in large numbers in plants functioning normally. The most numerous have been the flagellates *Trepomonas, Tetramitus,* and *Trigonomonas,* in that order. Such other flagellates as have been found have occurred so seldom they might be called adventitious. Next in importance have been the amoebae, the very small genera *Vahlkampfia* and *Hartmanella* being commonest. The ciliates *Metopus Trimyema* and *Saprodinium,* with occasional other bizarre forms, rank third.

Dual Biologic Population

Although these protozoa occur in wholly anaerobic situations, they are apparently facultative anaerobes and can live in the presence of oxygen. In Hays process treatment plants, which employ contact aeration, sewage which had undergone no treatment beyond primary settling flowed past plates on which a biological film developed. The air blown into these tanks was abundant, yet a huge population of the above-mentioned anaerobic protozoa developed in the film. The flagellates, most abundant, were saprozoic, but the ciliates and the amoebae, at least to some extent, ate bacteria. Relative numbers of organisms in three types of processes are shown in Table I. It should be stated, however, that the Hays process plants frequently contained additional huge populations of aerobic protozoa, rotifiers, and other animals often found in trickling filters, plus vast quantities of purple, brown, and green bacteria, and the identifyable sulfur bacteria *Beggiatoa* and *Chromatium*. Inasmuch as the colored bacteria occurred at the tops of the plates in the light, it may be inferred that they were autotrophic bacteria. Why they should be common only to this type of plant is enigmatic, unless their metabolism is dependent on sulfur. Patches of purple bacteria often occur around the tops of sewage treatment plants, but not in the numbers encountered in these Hays plants. Sulfates were abundant in the waters in question, and the numbers of sulfur bacteria indicated they reduced the SO_4. Usually, a smell of H_2S also was present. But how was this reduction accomplished in the presence of abundant oxygen? Sewage has a high oxygen demand and the oxygen acceptancy of this particular type of plant was probably equal to the amount available. Assuming a full utilization of available oxygen by oxidizable sewage, bacteria and aerobic animals left ideal conditions for the anaerobic organisms —immediately available food, turbulence, and a physically suitable substratum. The result was the co-existence of two large but morphologically and metabolically different populations.

That the biota of Hays plants is unusual applies only to the variety and abundance of bacteria, especially the autotrophic and sulfur forms, and to the numbers of facultative anaerobic protozoa. Many of the plants investigated were inefficient in purification; they were malodorous, they did not sufficiently reduce B.O.D., and the effluent contained too many bacteria. Evidently, for handling loadings comparable to those of activated sludge or Imhoff tank-trickling filter plants, the aerobic and anaerobic processes are not successful as simultaneous treatments.

Aerobic Processes

Activated sludge and trickling filters contain an essentially similar group of organisms as far as exact knowledge goes. Zoogleal bacteria are probably most abundant, and both types of plant contain filamentous bacteria and

TABLE I.—Organisms Present in 1 ml. of Liquid or Film at Various Depths (in Feet) for Three Types of Sewage Treatment Plants

Type of Organism	Imhoff Tank			Hays Plant	Trickling Filter		
	0	7	15	5	1	3	5
Ciliates	1,272	848	636	18,450	131,000	40,800	10,000
Flagellates	3,816	10,176	7,632	135,000	67,700	80,000	353,900
Rhizopods	—	—	—	57,000	15,900	12,800	19,200
Metazoa	—	—	—	—	9,400	10,200	6,400

filamentous fungi, although these last are usually more abundant in trickling filters and may be of different species from those of activated sludge. Species of protozoa are abundant and frequently vary from plant to plant, but functionally the same types are found. Rotifers, nematode worms, tardigrada, water mites, annelid worms, insect larvae, and snails usually occur, often in huge numbers, but often some one or more of these is lacking, perhaps because of the competition offered by a dominant form. *Acolosoma hemprichi* sometimes occurs in activated sludge in sufficient numbers to lend a pinkish tinge, and when this occurs other forms frequently decrease in number. When such an environment becomes anaerobic, as sometimes happens in high rate filters, there is a quick loss, with death, of these aerobes.

The kind, number, and role of many bacteria in aerated treatment is sufficiently known to need scant comment here. This is especially true of the zoogleal types. There is still need, however, of a more detailed enumeration of many of the freely motile forms, the *spirilli*, and the attached chain formers such as *Mycoides* and the *Chlamydobacteriales*. Not even the taxonomy of this last group is well known, and when an organism like *Sphaerotilus* is a factor in bulking it is accorded plenty of attention. However, its possible function in the assimilation of carbohydrates (15, 16) is of beneficial importance, hence should likewise be studied. *Sphaerotilus* or some closely allied form occurs in both activated sludge and trickling filters in great abundance short of bulking, but only when it causes trouble is it studied.

Aerobic Fungi

There is also considerable general knowledge of the more common fungi (17, 18) in aerobic treatment, but only a few have been fully identified. The operator has almost no chance of recognizing one which might be a cause of trouble, as was the case at Chicago a few years ago when one species grew so abundantly on the diffuser plates as to gradually dangerously limit the admission of air. It is known that filamentous organisms tend to secure (bind) the film on stones and also act as a center for floc formation in activated sludge. Just as certainly, however, *Zoogloea* can form flocs on any other base or with no base at all, and just as certainly they can be effective in reducing B.O.D. in the absence of any other organism, whereas the possible role of other bacteria and fungi in reducing B.O.D. has never been shown satisfactorily.

Besides the filamentous fungi, difficult to recognize as working (alive) or dead, there are many other colorless plants (possibly yeasts and actinomycetes), which are virtually unmentioned in the biology of sewage treatment. Their very abundance indicates a large role in purification, but what that role may be awaits further research.

Aerobic Animals

The animals of aerated processes are much better known, at least as to kinds. The protozoa are generally divided into those known to eat bacteria, and those about whose food there is uncertainty. There is a tendency, however, to accept the current lists as being inclusive, and to neglect those not definitely listed. For example, there is probably no more abundant species than *Diplophrys archeri*, but this very small rhizopod is almost unmentioned. Its huge numbers and rapid multiplication ought to make it important, but the manner of its importance is unknown. There is too little experimental work on the activities of protozoa. It is easy to grow many of them as bacteria-free cultures in flasks, and it would be a short step to develop such cultures and try to feed them on sewage, or to introduce them into sterile sewage under aeration, or into

sewage with a single species of bacteria. Work of this sort would lead out of the field of speculation and we permit experimental work on a plant scale. After all these years there is still no satisfactory way of enumerating the number of stalked ciliates (*Vorticellidae*) in a given volume of film or activated sludge. Nevertheless, the genus *Vorticella* has been stated to be one of the best indicators of the condition of activated sludge (19) and there is no doubt that *Vorticellidae*, because of their vast numbers, are capable of maintaining the biologic balance by tending to keep bacteria in check.

Little need exists for listing and showing the animals of aerated sewage, as many such lists are available. It is known that an organism such as *Paramecium* may be abundant in one plant but may be practically lacking in another, whereas the second may have a large population of *Blepharisma*. Both are bacteria eaters and presumably all such animals, whether protozoa, rotifers, or something else, keep the bacteria at a constant high reproductive, and therefore metabolic, level. At any rate, the over-all picture of sludges or films with an abundant and diversified animal population is one of a constant high B.O.D. removal, and a clear non-odorous effluent.

There are plants, however, where some single organism is vastly abundant. *Psychoda* larvae, snails, and worms fit this category. The nuisance value of *Psychoda* has resulted in efforts to control it, and apparently this problem has been solved. Another question, however, concerns the possible film removal activities of all three types. This should be tested, on a plant scale, to see whether enough film is eaten to interfere with B.O.D. removal, when the organisms are present in such quantities as at Oxford, Ohio (snails) or at Springfield, Missouri (worms). The problem has been partially dealt with by the use of D.D.T. in a number of places (20), but apparently not from the standpoint of an effect on B.O.D. removal. Tomlinson (21) states that D.D.T. had no deleterious effect on purification, when used to kill *Anisopus* and *Psychoda*. Brown (22) investigated the occurrence of snails at Champaign-Urbana (Ill.) and at Fort Worth (Texas), and found they ate organic matter, inferring that they reduced the number of bacteria. Most of the work ascribed to these higher organisms, however, is largely summarized by Reynoldson (23), who decided that they kept the beds open, provided good aeration, and reduced ponding. These are useful functions. If they lower B.O.D. removal—Van Kleeck (24) claimed that *chironomid* larvae impaired purification by eating the sludge—it should be known so that it could be dealt with.

The Atomic Age

Sewage has been treated for about 50 years, and today there is a large investment in expensive treatment plants. The American public is acutely conscious of the needs for efficiently functioning plants, for the protection of watersheds and water supplies, and for the elimination of pollution of streams and lakes. All of which makes an opportunity and a responsibility for those interested in sewage treatment. Plant superintendents and operators are an alert and forever-on-the-job group, and as a rule when some phase of plant malfunctioning occurs, they work at it until the problem is licked. Their troubles show little sign of decreasing, for they are constantly called on to treat more and more industrial wastes and still produce an effluent "clear, sparkling, and saturated with oxygen." A recent magazine article (25) contains the statement, "Suppose, now, that we are draining into a sewer, stream, or bay, radioactive wastes sufficiently diluted . . .," which puts the operator squarely in the atomic age and warns him that

he must learn whether isotope Te^{132}, or perhaps plutonium, will ruin his film or sludge.

Much Still Unknown

Mechanical and chemical problems are susceptible to rule of thumb or analytic solution. All too frequently, however, an operator's headache is of a biological nature, and too little is still known of this process. Things that must be known are: first, more precise information on the species of each group of organisms working in treatment plants; second, the relative abundance of each, so that no important (numerically or volumetrically) organism is neglected; third, the range—not the optimum, but the range—of environmental conditions under which the organism works; and fourth, the work accomplished—whether a small segment of the purification process, or a large one.

How can the plant superintendent or operator obtain this information? The basic need for precision in sewage treatment today is intensive research in sewage biology; a questing by competent bacteriologists, mycologists, and zoologists concerning the organisms cultivated in treatment plants. Almost any treatment plant today has a good microscope as part of its standard equipment, and when something goes wrong the harassed operator studies a slide. However, unless the predominant organisms mean something to him, nothing is gained.

The larger treatment plants can each support some phase of biologic research, just as they do other experimental work, and correlation of the results will go far towards standarization of tests and interpretation of results.

References

1. Hall, George L., "Dense Algal Growths in Streams Stimulated by Sewage Effluent." *Sewage Works Eng.*, **18**, 94 (1947).
2. Gaub, William H., Jr., "A Bacteriological Study of a Sewage Disposal Plant." *Bull. 394*, N. J. Agr. Exp. Sta. (1924).
3. Hotchkiss, Margaret, "Studies on the Biology of Sewage Disposal: A Survey of the Bacteriological Flora of a Sewage Treatment Plant." *Amer. Jour. Bact.*, **9**, 437 (1924).
4. Hotchkiss, Margaret, "Studies on the Biology of Sewage Disposal: A Sprinkling Filter Bed and Its Bacteriological Population." *Amer. Jour. Bact.*, **9**, 455 (1924).
5. Hotchkiss, Margaret, "Bacteriological Studies on Imhoff Tanks." In *Fourth Annual Report*, Sew. Substation, N. J. Agr. Exp. Sta.
6. Heukelekian, H., and Littman, M. L., "Carbon and Nitrogen Transformation in the Purification of Sewage by the Activated Sludge Process. II. Morphological and Biochemical Studies of Zoogleal Organisms." THIS JOURNAL, **11**, 752 (1939).
7. Heukelekian, H., and Schulhoff, H. G., "Studies on the Clarifying Organisms in Activated Sludge." THIS JOURNAL, **10**, 43 (1938).
8. Heukelekian, H., and Chamberlin, N. S., "Biochemical Changes and Loss of Nitrogen During Prolonged Aeration of Sewage." *Ann. Report*, Dept. of Water Supplies and Sewage Disposal, N. J. Agr. Exp. Sta. (1932).
9. Heukelekian, H., and Heinemann, Bernard, "Studies on the Methane Producing Bacteria. I. Development of a Method for Enumeration." THIS JOURNAL, **11**, 426 (1939).
10. Butterfield, C. T., "Studies of Sewage Purification. II. A Zoogloea-Forming Bacterium Isolated from Activated Sludge." *Pub. Health Reports*, **50**, 671 (1935).
11. Butterfield, C. T., and Wattie, Elsie, "Studies of Sewage Purification. XV. Effective Bacteria in Purification by Trickling Filters." *Pub. Health Reports*, **56**, 52 (1941).
12. Wattie, Elsie, "Cultural Characteristics of Zoogloea-Forming Bacteria Isolated from Activated Sludge and Trickling Filters." *Pub. Health Reports*, **57**, 41 (1942).
13. Lackey, James B., "The Fauna of Imhoff Tanks." *Bull. 417*, N. J. Agr. Exp. Sta. (1925).
14. Liebmann, Hans, "Die Ciliatenfauna der Emscherbrunnen." *Zeits. Hyg. u. Inf.-Krankh.*, **118**, 555 (1936).

15. Lackey, James B., and Wattie, Elsie, "Studies of Sewage Purification. The Biology of *Sphaerotilus natans Kutzing* in Relation to Bulking of Activated Sludge." *Pub. Health Reports*, **55**, 22 (1940).
16. Wilson, John N., "Microbiota of Sewage Treatment Plants and Polluted Streams." Paper delivered before the Limn. Soc. of Amer. (Dec. 30, 1947).
17. Rudolfs, Willem, and Trajkovich, Helen A., "Fungi and Algae of the Sprinkling Filter Bed and their Distribution." In *Third Annual Report*, Sew. Substation, N. J. Agr. Exp. Sta.
18. Tiesenhausen, Manfred, "Beitrage zur Kenntnis der Wasserpilze der Schweiz." *Archivs f. Hydrobiol. u. Planktonkunde*, **7** (1912).
19. Reynoldson, T. B., "Vorticella as an Indicator Organism for Activated Sludge." *Nature*, May 30, 1942, p. 149.
20. Carollo, John A., "Control of Trickling Filter Flies with D.D.T." THIS JOURNAL, **18**, 2 (1946).
21. Tomlinson, T. G., "Control by D.D.T. of Flies Breeding in Percolating Sewage Filters." *Nature*, Oct. 20, 1945, p. 146.
22. Brown, Thelma Fish, "The Biology of *Physa anatina Lea*, a Snail Living in a Sewage Treament Plant." *Am. Mid. Nat.*, **18**, 2 (1937).
23. Reynoldson, T. B., "The Biology of Macro-fauna of a High Rate Double Filtration Plant at Huddersfield." *Proc.*, Inst. of Sew. Purif., 1–16 (1941).
24. Van Kleeck, B. Le Roy, "The Chironomid Fly." *Munic. Sanit.*, **11**, 6, 285 (June, 1940).
25. Western, Forrest, "Problems of Radioactive Waste Disposal." *Electronics*, **3**, 2 (1948).

THE BIOLOGY OF SEWAGE TREATMENT—A DISCUSSION

By Gerard A. Rohlich

Associate Professor, Laboratories of Hydraulic and Sanitary Engineering, University of Wisconsin, Madison, Wis.

The difficult task of summarizing, in a brief paper, the vast amount of work that has been done on the biological aspects of sewage treatment, has been ably performed by Dr. Lackey. We are fortunate in having his continued interest in this subject, which as he has pointed out, still offers a fertile field for investigation, and even more so for a correlation of some of the results thus far obtained.

Definite progress, however, has been and is being made in understanding and controlling some of the fundamental biochemical reactions that take place in the various unit processes of sewage treatment works. The early biological survey work on sludge digestion by staff members at the New Jersey State Experiment Station, referred to by Dr. Lackey, has been followed by more detailed studies on the methane producing bacteria by Heukelekian and others (1). More recently, the report of Buswell (2) on the isolation of the *Methano sarcina* form capable of producing methane from calcium acetate has, in his own words, "opened up the possibility of the control of the digestion process in a manner approaching that used in other fermentation industries, so that it would now appear quite feasible to prepare cultures in large quantities which would carry a sufficient number of the proper organisms so that a reasonable amount of inoculum would insure rapid digestion in a new tank, or in an old tank which is operating unfavorably."

The unusual biological conditions in the Hays process plants referred to by Dr. Lackey are of particular interest. It is to be remembered that the spacing between the contact plates in most of these plants was about 1½ in., and that in many of the plants, although a more than adequate air supply was provided (as compared to activated sludge), there was poor distribution of air and short circuiting. Although to the naked eye there existed "side

by side two large but morphologically and metabolically different populations," in microscopic distance they were widely separated, thus making it possible that reduction occurred on the underside of the film where anaerobiasis was dominant. It is believed that a similar condition occurs in lakes having a heavy "bloom." Although, by test, the water may have a high oxygen content, anaerobic decomposition does occur in the thin film on the surface where the organic material from the dead organisms is present.

Dr. Lackey has pointed out that the role of bacteria in aerated treatment is well known, but that additional experimental work on the activities of protozoa (and, it might be added, other higher forms of life) is needed. This is all too true. In the activated sludge and trickling filter processes bacteria exist in large numbers. Being in the limelight they are usually given the credit for the success of the process, with the protozoa usually considered as serving only as regulators of bacterial numbers. Cramer (3) and Wagner (4) demonstrated this regulatory function of the protozoa several years ago. Wagner used a small model sewage purification tank, to which was added such inhibitors as quinine sulfate and potassium cyanide to destroy the protozoa and allow the bacteria to grow. The latter increased tremendously in numbers, but the sewage purification was adversely affected. On renewal of the protozoan fauna, the bacteria were again reduced in numbers, but the purification was restored to its original high efficiency. This is well known at present and considerable additional work and verification of this study has been made by others.

More recently Hardin (5) and Watson (6) showed that, in addition to acting as regulators of bacterial population in aeration processes, the protozoa also brought about flocculation of bacteria. Hardin worked with the flagellate, *Oikomonas termo*, and Watson with the holotrichous ciliate, *Balantiophorous minutus*. Watson points out the power of this organism in causing flocculation of the bacteria on which it feeds, a property which he states is "obviously of value to the organisms themselves, since it facilitates the collection of food bacteria; and may also be of importance in sewage purification." The feeding mechanism involves the production of mucus, secreted within the peristome, to which the food bacteria adhere before being ingested, and are thus prevented from being swept out by ciliary currents. This mucus has been found gradually to accumulate in the culture fluid and as it is not a diffusible substance, it remains in the neighborhood of the ciliates themselves. The resulting local increase in the viscosity of the culture medium causes the entanglement and flocculation of the bacteria. When examined under the microscope the floc shows that the bacteria are cemented together by an amorphous substance, which by means of staining shows the characteristics of mucin.

The work of Pillai and Subrahmanyan (7) in India, however, appears to place undue emphasis on the role of the protozoa. The ciliate *Epistylis sp.* was used in their studies, and they concluded that "the isolated protozoa can bring about practically all the changes associated with the purification." The part played by the bacteria is claimed to be almost negligible. They state that further evidence is available to show that the conditions affecting the life and activity of the protozoa also affect the efficiency of the purification. In examining sludges from activated sludge and other aerobic systems of treatment from various parts of India they conclude that the presence and active functioning of protozoa is evident wherever the purification is proceeding satisfactorily, and that if the protozoa are absent or

found dead or encysted, there is no purification. Further investigation along these lines is warranted. It is questionable that the role of the bacteria is almost negligible, as has been stated by these workers.

All these findings present a new aspect of the role of the protozoa in the field of sewage treatment, and point the need for further study on not only these organisms, but also on other higher forms of life. The complexity of the subject is such that no simple explanation will suffice. The truth of this was well worded in one of the early reports of the New Jersey Agricultural Experiment Station which stated, "the living aggregate of associated organisms rather than any simple type or group of creatures is significant in the purification of sewage."

Dr. Lackey has outlined very clearly and concisely in his four points the information needed for a fuller understanding of the biology of sewage treatment. The importance of biology is not limited to the treatment of sewage alone, but, as is well known, is of vital importance in the ecology of our lakes and streams, and also in the proper application and understanding of such tests as the B.O.D. determinations, in which the presence or absence of certain flora and fauna can greatly modify the results that are obtained. Attention recently has been called to the effect of the nitrifying organisms in increasing the B.O.D. values, and to the effect of toxic substances in depressing the magnitude of the B.O.D. These are subjects beyond the scope of the paper, however, but emphasize the need for the further work as outlined by Dr. Lackey.

References

1. Heukelekian, H., and Heinemann, B., "Studies on the Methane Producing Bacteria. I. Development of a Method for Enumeration." THIS JOURNAL, **11**, 3, 426 (May, 1939); "II. Enumeration in Digesting Sewage Solids." THIS JOURNAL, **11**, 3, 436 (May, 1939).
2. Buswell, A. M., "Important Considerations in Sludge Digestion. Part II. Microbiology and Theory of Anaerobic Digestion." THIS JOURNAL, **19**, 1, 28 (Jan., 1947).
3. Cramer, Robert, "The Role of Protozoa in Activated Sludge." *Jour. Ind. and Eng. Chem.*, **23**, 309 (1931).
4. Wagner, G., "The Biological Principle in Sewage Purification by Activated Sludge Method." Anniversary Publication 25 yr., Danzig Tech. School Reprint, *Wasser Abwasser*, **26**, 217.
5. Hardin, G., "Flocculation of Bacteria by Protozoa." *Nature*, **151**, 642 (1943).
6. Watson, J. W., "Mechanism of Bacterial Flocculation Caused by Protozoa." *Nature*, **155**, 271 (1945).
7. Pillai, S. C., and Subrahmanyan, V., "The Role of Protozoa in Aerobic Purification of Sewage." *Nature*, **154**, 179 (1944).

Industrial Wastes

DAIRY WASTE DISPOSAL *

By Edward F. Eldridge

Director and Chief Engineer, State of Washington Pollution Control Commission, Olympia, Wash.

Like most industries in the United States the dairy industry has organized on a nationwide basis to study the waste disposal problem. The major element in this effort is a Task Committee on Waste Disposal, appointed by the Subcommittee on Dairy Standards and consisting of representatives of the various branches of the industry. Its functions include the collection and dissemination of information on subjects relating to the disposal of the waste from the industrial processes. The Task Committee is also to be of general assistance to the various members of the industry on their individual problems.

About a year ago an agreement was made between the Task Committee and the Engineering Experiment Station, Michigan State College, to cooperate on certain phases of the studies being considered. These cooperative activities were to include the collection and publication of information on practical methods of waste prevention, and pilot-plant and full-scale studies of waste treatment. Because as much of the material relating to waste prevention has been collected and will be published in detail in a bulletin of the Task Committee, reference in this paper to waste prevention is limited to a discussion of the results of a specific problem.

Two plants were selected for the study of waste treatment. The first was the full-scale activated sludge plant located at the Belle Center Creamery and Cheese Company, Belle Center, Ohio; the second was a pilot-plant designed and built by the Station on the premises of the Detroit Creamery Company at Ovid, Mich.

The studies at Belle Center have been completed and considerable information has been collected. However, as it is a full-scale plant it was not sufficiently flexible to allow the variations necessary for a research study. The most valuable and significant result of the operation of this plant has been the consistently excellent effluent obtained under widely variable conditions. The work at Ovid has only been underway for a short time and the information collected to date is rather meager. Because the subject of milk waste disposal is too large to be covered in its entirety in this paper, the material herein presented is limited to that collected since the work for the Task Committee was started.

Waste Prevention

It is a demonstrated fact that waste prevention measures, when properly applied, will do more toward the reduction of the strength of the wastes discharged from a milk products plant than can be accomplished with the same effort applied to waste treatment. Such measures appear to be more easily applied to milk plants than to most other types of industries. The first item, therefore, of a waste disposal program should be waste prevention.

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations; Detroit, Mich.; October 18–21, 1948.

This item requires ingenuity on the part of the plant management, and the cooperation of the employees. It is definitely tied in with plant operation.

When the writer undertook a study of the waste disposal problem of the Belle Center Creamery Company last year a program of waste prevention was initiated for the receiving room and cheese operations.. This was preliminary to the design of treatment facilities.

Normal operations, as represented by the B.O.D. results obtained during the first week, showed a waste varying from 240 to 1,200 lb. of B.O.D. per day. It is obvious that to provide adequate treatment for such a variable load would not be practical and would be very costly, as it would be necessary to design for the maximum load. Although the results of the prevention program show that the waste was reduced from an average of 500 lb. to 150 lb. B.O.D. per day, the most significant result as far as waste treatment is concerned was the production of a waste of more uniform load. This is an essential factor in the successful operation of a waste treatment plant and the lack of such uniformity is undoubtedly the explanation for unsuccessful operation in many existing plants. There is no legitimate reason for wide variations in the waste from milk plants. Such variations indicate carelessness and lack of understanding on the part of the management and employees.

The waste prevention program at Belle Center resulted in a reduction of from 60 to 70 per cent of the B.O.D. load to be treated. The milk intake was not responsible for the reduction, as during this time the intake increased about 50 per cent. The major items responsible for the reduction were:

1. The collection of drip and first rinse from the can washer.
2. The collection of first drainage from raw milk storage tanks.
3. The installation of electronic alarms on storage tanks to prevent overflow.
4. A direct connection between whey pump and piping and the cheese vats.
5. A pan under the cheese press to collect the press water.
6. An educational campaign among plant employees.

Activated Sludge at Belle Center

A flow diagram of the activated sludge plant at the Belle Center Creamery and Cheese Company is shown in Figure 1. This plant was originally designed for another process and later adapted to activated sludge. For this reason, some of the features might have been different had they been originally designed for this process.

The waste from cheese operations and the condensate from the vacuum pans (supplemented by waste from a milk sugar operation when it is desired to increase the load) flows to an equalizing sump. Air is applied in this sump to prevent septic action and odor production. Two pumps are used to lift the waste to a division box, where the desired quantity is discharged to each of two aeration tanks. These tanks are divided into three compartments to prevent short-circuiting. The effluent from each aeration tank flows to a separate clarifier so that there are in reality two separate activated sludge units in this plant, each consisting of an aerator and clarifier. The effluent from the clarifiers flows through a weir box to the outfall sewer.

Return sludge from each clarifier is lifted by an air-lift pump to a weir box, from which it flows into the respective aeration tanks. Excess sludge is collected in a small concentration tank, from which the concentrated sludge is pumped to the digester and the upper liquor discharged to the effluent weir box.

Air is supplied by three positive pressure blowers of 250 c.f.m. capacity

each, one of which is used as a standby. Self-cleaning jet diffusers are used in the aeration tanks. The capacities of the various units are as follows:

Preaeration sump.	12,500 gal.
Aerator, total	23,760 gal.
Clarifiers, total	23,950 gal.
Digester	11,450 gal.

Conditions at Belle Center require an effluent B.O.D. below 50 p.p.m. and a waste flow not greater than 35,000 g.p.d. at all times. This requirement made accurate control necessary and handicapped the experimental work to some extent, as it was not possible to attempt variations which would adversely affect the effluent.

Table 1 shows the results of the plant operation for a typical month (July, 1948). These results indicate a considerable variation in the B.O.D. load applied—136 to 350 lb. per day. This variation did not materially affect the effluent, as for the most part the loading was below the capacity of the plant as established by the operating data. The average load for the month was 243 lb. per day; the average effluent B.O.D., 11 p.p.m.

Using the data given in Table 1, together with the capacity data previously given, it is apparent that: The average aeration period based on raw waste flow was 20.6 hr., and based on total flow, including return-sludge, was 4.9 hr.; the average detention period in the clarifiers was 5 hr.; and the average overflow rate of the clarifiers was 115 g.p.d. per sq. ft. It is recognized that the clarifiers are probably larger than

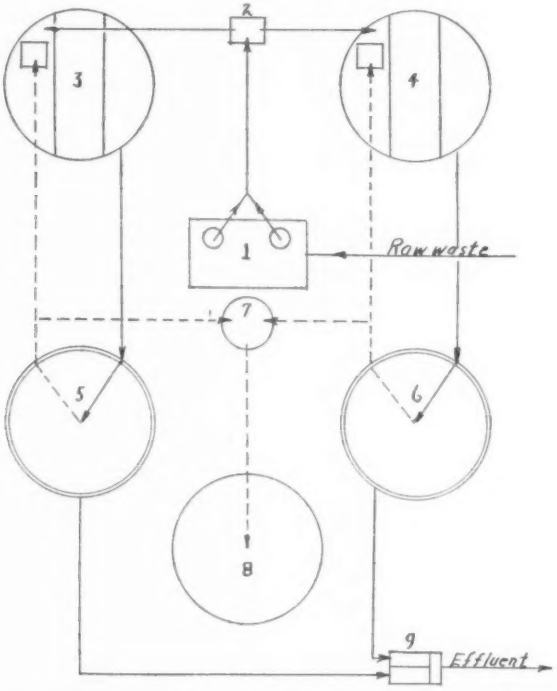


FIGURE 1.—Flow diagram of Belle Center Creamery activated sludge plant showing: (1) aerated influent sump; (2) division box; (3 and 4) aerators; (5 and 6) clarifiers; (7) sludge concentrating tank; (8) digester; and (9) effluent weir box.

TABLE I.—Results of Activated Sludge Treatment, Belle Center Creamery and Cheese Company

1948 July	Raw Waste			Final Effluent B.O.D. (p.p.m).
	Flow (g.p.d.)	B.O.D. (p.p.m.)	B.O.D. (lb.)	
1	38,820	no test	—	no test
2	36,120	1,052	316	5
3	19,395	973	157	7
4	24,480	960	195	10
5	34,470	1,063	304	14
6	37,410	963	299	12
7	28,800	1,031	246	7
8	35,100	1,207	350	19
9	33,500	1,067	296	9
10	30,450	1,015	256	5
11	32,130	933	248	13
12	32,500	no test	—	no test
13	23,280	972	187	34
14	20,835	no test	—	no test
15	30,485	845	214	11
16	30,780	845	216	19
17	36,720	550	168	8
18	36,290	890	268	36
19	30,340	no test	—	no test
20	20,580	1,127	192	20
21	25,860	1,200	258	8
22	33,390	1,063	294	13
23	32,520	1,273	344	11
24	24,060	1,030	206	11
25	20,820	787	136	4
26	23,520	1,013	198	4
27	37,920	925	292	4
28	27,420	922	210	4
29	31,440	925	242	3
30	35,160	770	224	4
31	36,330	855	258	6
Average	30,353	936	243	11

necessary, but because they were existing structures they were incorporated in the plant without change. There is one advantage in the low overflow rate; no matter how bulky the sludge, very little ever passes over the weir of the clarifiers.

The results of the operation of the activated sludge process with the waste at Belle Center, which may be considered a typical cheese factory waste, somewhat establish the following factors:

1. The minimum aerator capacity to insure an effluent B.O.D. consistently below 50 p.p.m. should be 80 gal. per pound B.O.D. per day. At least this is the case where the aerator-clarifier capacity ratio is 1 to 1. Under these conditions, the present two units at Belle Center are capable of treating a B.O.D. load up to 300 lb. per day.

2. The volumetric loading is naturally dependent on the B.O.D. concentration of the waste. In the case of a waste having a B.O.D. of 1,000 p.p.m., which is considered typical for dairy wastes, the volumetric detention period should be about 16 hr. based on the raw waste flow.

3. A dissolved oxygen content of 1 to 4 p.p.m. in the aerator and a trace or more in the clarifier must be maintained.

4. The percentage of return-sludge flow depends on the B.O.D. concentration. Considerable work is still necessary to establish the return-sludge ratio to raw waste flow. However, it appears that within a range of from 800 to 1,400 p.p.m. B.O.D. the flow of return sludge will vary from 600 to 700 per cent of the raw waste flow.

5. The required suspended solids concentration in the mixed liquor will vary from 5,000 to 6,000 p.p.m. where the waste treated has a B.O.D. within the range indicated above.

6. The optimum settling characteristics of the solids in the mixed liquor appears to be that which will produce 300 ml. of sludge per liter of liquor in a period of one hour. However, with the aerator-clarifier ratio of 1 to 1 as exists at Belle Center, even the liquor with a settling rate up to 800 ml. per liter in one hour usually produces a satisfactory effluent. In fact, the effluent from slow-settling or bulky sludge appears to be much better clarified than that with sludge which settled too rapidly. Overloading usually produces a bulky sludge due largely to under aeration or lack of sufficient time to complete the oxidation process. Excessive carbohydrate to protein ratio also tends to produce a light

sludge and a change in the type of organisms which predominate in the sludge. Bulking sludge, however, is not as objectionable with high concentration waste as it is with domestic sewage, as the low volumetric load allows a lower overflow rate in the clarifier.

7. The optimum air requirement using the jet diffuser was about 1 to 1.2 c.f.m. per pound of B.O.D. per day. Preaeration required about 0.5 c.f.m. per pound of B.O.D. per day to prevent septic conditions and odors.

8. The excess sludge volume at Belle Center was fairly large and averaged about 3,300 g.p.d. This volume was reduced in the concentrating tank to about 1,300 g.p.d., or a reduction of 60 per cent. It is obvious that this concentrating tank was of value in reducing the sludge volume to the digester, and consequently the supernatant flow. The detention period in the digester based on the July report was approximately 9 days, yet it has not been necessary to draw digested sludge, even though the digester has been in operation for almost a year. It is apparent that the solids are completely liquified and gasified, which is a condition to be expected with organic material that contains no fibrous or cellulose material. The temperature of the digester is maintained at 90° F., using steam from the plant.

Pilot Plant at Ovid

The pilot plant at Ovid is designed for a study of the following items of milk waste treatment:

1. Aeration without return sludge.
2. Biofiltration with and without preaeration.
3. Activated sludge with or without preaeration.
4. Sludge digestion using sludge from both filtration and activated sludge.

This plant and the results of its operation will undoubtedly be the subject of future publications. This does not appear to be the appropriate time to go into a detailed explanation of this

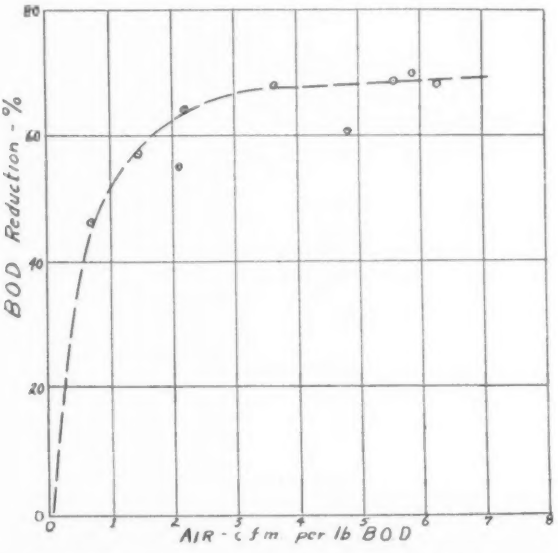


FIGURE 2.—Air requirements vs. B.O.D. reduction.

project and the discussion herein is limited to some general items of interest in connection with this study.

The primary purpose of the project is to determine practical and economical design data for the construction of treatment units. Each of the combinations listed above is capable of producing a certain degree of treatment and an effluent of more or less definite characteristics. When these characteristics are established it will be possible to select the type of treatment adapted to specific plant problems.

There are many items in connection with waste treatment which affect the cost of treatment facilities. These items will be studied in view of their affect on the efficiency of the various processes. For instance, the first item selected for this study was a comparison of air requirements and B.O.D. reduction using aeration without return sludge. Figure 2 gives a curve prepared from limited data collected to date. The aeration period was 20 hours. It is apparent that about 40 per cent reduction in B.O.D. is accomplished with a rate of application of 1 c.f.m. per pound of B.O.D., 52 per cent with 2 c.f.m., 58 per cent with 3 c.f.m., and 62 per cent with 4 c.f.m. The B.O.D. concentration of the raw waste was between 700 and 800 p.p.m.

The practical use of this data is apparent. If a satisfactory effluent is possible using plain aeration and 2 c.f.m. of air, this method of treatment will undoubtedly prove less costly and less complicated than filtration or activated sludge. Self-cleaning jets were used in the above tests. Eventually other types of diffusers will be installed and similar tests made to compare their efficiencies.

This is a study that will require a long period of time and the collection of a large amount of detailed data. Its value will be not only in relation to milk waste treatment, but also in possible applications to the treatment of other types of waste.

BIBLIOGRAPHY ON RADIOISOTOPES AVAILABLE

A selected bibliography, specifically designed to acquaint the sanitary engineer with fundamental information on safe use and disposal of radioactive materials, has been prepared by the Isotopes Division of the U. S. Atomic Energy Commission. Major topics covered include general popular and technical information, radioactivity units and tolerance doses, waste disposal and tolerance concentrations, instrumentation, survey techniques, the handling of radioactive materials, and radiation shielding.

Copies of the 3-page mimeographed circular may be obtained by requesting "Isotopes Division Circular B-8" from the U. S. Atomic Energy Commission, Isotopes Division, P. O. Box E, Oak Ridge, Tenn.

WASTES FROM CHEMICAL MANUFACTURING*

By Raymond W. Hess

Head of Pollution Research and Operating Improvements, National Aniline Division, Allied Chemical and Dye Corp., Buffalo, N. Y.

The manufacture of a chemical generally involves chemical reactions between raw materials to give the desired product. The same chemical reactions and side-reactions usually give by-products having little or no value. Reactions that cannot be made to go to completion result in leaving some raw materials unchanged. Addition of solvents, diluents and other substances to promote the desired reactions, and precipitants for isolation of the desired material from solution, are frequently necessary. Procedures for purifying the desired product give additional by-products. The resulting mixtures of so many kinds of substances, frequently in very dilute solution, is so complex that, for the most part, they cannot be recovered with any monetary return. For many, there are no known or visualized methods of recovery. Frequently, there are several pounds of these wastes for each pound of the desired material.

Corrective Action

The chemical industry is attempting to determine the nature and extent of the need for diverting its wastes from public waters by participating in stream surveys of receiving waters and their capacities for self-purification as related to dissolved oxygen, oxygen balance, B.O.D., pH, toxicity, solids, color, etc. In view of the high costs for corrective action with which it, and thereby the public, is confronted, the industry is greatly concerned about having these characteristics soundly related to the uses of the receiving waters.

Following such a survey, even though it may not be fully satisfied with the objectives proposed by the authorities, a manufacturing plant then proceeds to determine its contribution to the total pollution load in its receiving waters. In this connection it develops related data for its sewer outlets by measuring volumes and analyzing the effluent over an extended period of time. This frequently means installation of automatic measuring and sampling devices. With few exceptions, such as for neutralization of waste acids and then only in a few cases, is this approach, alone, recognized to be adequate to determine the nature and extent of corrective action needed in the interest of sound sanitary science and economies.

Generally, the next step is to investigate the loads for each pollution characteristic of concern in major waste liquors at their individual process sources. This may show that corrective action for these wastes alone is adequate to meet stream requirements. Even for such relatively simple pollution characteristics as acidity, the information developed may lead to sounder corrective action related to reducing the amount of waste acid produced or to handling a much smaller volume of liquor in neutralization.

In view of the high costs for corrective action, the chemical industry is also greatly concerned as to the significance of the standard methods of

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations; Detroit, Mich.; October 18–21, 1948.

analyses for pollution characteristics in their relationship to the effects of wastes on the stream. It is of the opinion that the B.O.D. determination leaves much to be desired in this connection, but uses it in the absence of some better test.

It does not have any more confidence in chemical methods using permanganate, dichromate, iodic acid, chlorine, etc., for this purpose. In the use of these oxidizing chemicals, as a short cut for calculating B.O.D., the chemical industry finds that there is no generally constant relationship to B.O.D. Nevertheless, these chemicals have been found to be time savers and to be less costly for estimating the B.O.D. of different samples of the same kind of waste, for which no definitely related methods of chemical analysis for components are known. In case the B.O.D. per unit of component and the method of chemical analysis are known, analysis for components may be an even simpler method for arriving at the B.O.D.

Experience shows that the methods of analysis now used for phenols and cyanides, in the presence of so many other substances found in process effluent and receiving waters, are inaccurate.

As for the determination of suspended solids, the industry emphasizes the importance of having this done at the eventual dilution, whether in the stream or at the municipal disposal plant, as much material which is undissolved at process concentration may be dissolved at greater dilution. The industry also desires to have a careful distinction made between unstable and inert materials as to their effects on receiving waters.

In regard to the toxicity of its wastes to aquatic life, the industry is concerned about having the tests made in the presence of other components normally present and at dilutions in the area where normal aquatic life is sensibly expected to exist.

Determination of color in relationship to its effect on the stream is very difficult. A method sometimes used is to find out the amount of water required to duplicate a platinum-cobalt standard. This is called the color dilution value. The amount of dilution required will depend on the nature and amount of other components in the receiving water. Furthermore, the amount of dilution required for individual wastes, considered separately, usually adds up to a higher value than the amount of dilution required if the wastes are first mixed together, and varies according to the proportion of each in the mixture.

Industry wishes to have critical attention given to any contention that color of wastes alone, aside from other properties, has harmful effects in receiving waters when the cost of elimination is high, as it usually is. A highly colored waste may contain a small amount of harmless material, whereas a colorless waste may have a high B.O.D. or be very poisonous. A solution containing a mixture of small amounts of pure food colors will have a very dirty appearance, but will be harmless.

In connection with diversion to municipal disposal systems, when a charge is made for chlorine, the industry contends that the chlorine demand should be determined with sewage at disposal plant dilution, rather than with a fixed proportion of water according to standard methods. It has been found that this method gives a much lower demand and that it is not due, for the most part, to mere dilution, but rather to the effect of sewage on the waste.

Corrective Measures Being Investigated and Applied

Corrective measures being investigated and applied by the chemical industry for the prevention and abatement of stream pollution are of the following types:

1. Recovery of by-products for plant use or sales.
2. Modification of productive processes to eliminate or reduce pollution.
3. Treatment of wastes liquors with no monetary return.
4. Diversion of waste liquors, with or without preliminary treatment, to municipal disposal plants.
5. Controlled dilution in receiving waters.

The most that can be hoped for, with few exceptions, from recovery of by-products by the chemical industry is partial payment of the costs for prevention and abatement of pollution. Unlike some industries, the chemical industry was developed from the beginning by scientific methods to favor maximum yields and the utilization of all by-products of value. No value is visualized at present for most of the remaining by-products. Although it appears that as a whole, accomplishments along this line will fall far short of the objectives for pollution abatement, the possibilities of salvage are receiving serious attention.

Something is being accomplished by modification of manufacturing processes to avoid or reduce pollution, but here again the possibilities are distinctly limited because of the scientific manner in which the chemical industry has been developed. Nevertheless, processes are being reexamined critically for possibilities of reducing objectionable by-products. It is found that in some cases there are excessive amounts of raw materials that can be eliminated, in some cases the amounts of diluents and solvents can be reduced, and in other cases the nature of materials in waste liquors can be altered to be less objectionable. In this connection the chemical industry is striving to minimize pollution in the conceptive, research, and development stages of new manufacturing processes.

After having considered the foregoing possibilities without finding anywhere near a complete solution to the problem, critical examination is made of the possibilities for disposal without any monetary return. Still practicable methods for diverting all wastes from public waters are not found. The chemical nature of the wastes and their effects on receiving waters are so greatly diversified that no one general method of treatment is possible and no wholly satisfactory methods of treatment for all individual or selected groups of wastes are known or visualized. Chemical, biochemical, or engineering methods would not be generally or even specifically applicable to all wastes. Generally, these methods require large tracts of land (for mixing, treating, sedimentation, and holding), which are unavailable to some plants. Not even neutralization and evaporation to dryness would be a technical solution, as volatile materials would present atmospheric pollution problems of major magnitude. Even if no atmospheric pollution problems were encountered and if industry could bear the extremely high cost, suitable repositories for the millions of tons of residues cannot be visualized.

Treatment with no monetary return in some cases includes conversion to gaseous products discharged to the atmosphere, but in most cases the impossibility of conversion to gaseous products, as well as the air pollution problem, greatly limits this type of application. Furthermore, some of the present stream pollution problems are due to conversion of gaseous wastes to liquid wastes to reduce atmospheric pollution.

Diversion to municipal disposal plants is being given more and more attention; but even here the opportunities are distinctly limited and, in some cases, very expensive. Many wastes are harmful to the structures or processes of the disposal plant. Some cannot be treated effectively by the processes used. For many manu-

facturing plants this method of disposal requires, at least, collection of individual or group wastes from widely separated areas and installation of complicated and expensive sewer systems. Sewer taxes for treatment may be very high when charges are made for chlorine demand and may be out of proportion to the sanitary improvement effected.

Finally, there is controlled dilution in receiving waters. One method involves long periods of holding, and discharge during periods of high stream flow. Some companies employ this method, apparently with satisfactory results, but the large tracts of land or the large volume of receiving waters required are not available to many plants. Another method involves substitution of cleaner water, in place of that of the waste receiving stream, in process cooling, and discharge into the stream after use to aid natural purification processes. The possibilities of this method as a supplement to waste treatment is being developed for the Buffalo River at Buffalo, N. Y. A third method consists of controlling the flow in streams so as to be more uniform throughout the year, thereby providing opportunities to utilize more of the stream's natural purification capacity. This would seem to be a government responsibility.

The chemical industry realizes that the possibilities for all these methods must be investigated thoroughly in the interest of prevention and abatement of stream pollution, but obviously they will vary between different plants depending on the status of development for their productive processes, the nature of their wastes, the land available for treatment processes, the nature of the public sewage system, the sources of water supply, the uses and volume of receiving waters, and the nature of related atmospheric pollution problems.

Whenever the nature and amount of improvement required allows a choice of methods, it is sometimes difficult to accept that method which gives no monetary return as being less costly when that is actually the case. The hope for salvage which will give a lower cost is naturally very persistent.

Chemical plants usually have relatively few wastes, from a limited number of major products, which may represent a substantial proportion of their pollution loads. These can sometimes be treated to advantage individually. Many also have wastes from most of their products which are unimportant individually, but add up to give a pollution load equal to or greater than that for the few major products. In most cases, individual treatment is not practicable because of the large number and small volumes of these wastes. The treatment problem for mixtures is much more involved than that for the major individual wastes because of the great number of and variations in kinds of components, due to frequent changes in the types of chemicals produced. The first essential is large retention capacity to equalize these variations. Furthermore, a process developed for one plant may not be applicable to another because of radical differences in the composition of waste liquors.

Methods for practically complete elimination of pollution by domestic wastes are known, yet they are not being fully applied. Methods for complete diversion of chemical wastes from public waters are not known, nor are they visualized at any cost at present.

Soluble Organic Substances

Soluble organic substances include carboxylic acids, sulfonic acids, the salts of both, alcohols, aldehydes, amines, nitro, sulfur and halogen compounds, and a host of others. The exact composition of many is unknown. Generally, they are produced in dilute water solutions and, even from a single process, are frequently mixed with much larger quantities of other classes

of wastes, such as inorganic acids and salts. Most of them have B.O.D. and some of them give color, taste, and odor problems.

Theoretically, all organic compounds composed only of carbon and hydrogen can be oxidized to carbon dioxide and water, with elimination of pollution; but those containing nitrogen, sulfur, and the halogens would leave residues as nitrates, sulfates, and halides. However, no one method of treatment is applicable and no methods are yet known for destroying all these substances. All conceivable methods of treatment are complicated by the presence of other substances.

Some of the less complex liquors containing phenols, acetic acid, and formaldehyde are being oxidized successfully on biochemical filters. Investigation of this method is being actively applied to other substances. Anaerobic treatment is also being investigated.

At least one company is operating a biochemical treatment process for mixed wastes similar to the activated sludge process for sanitary sewage. That company has developed an installation, some details of which are being used in sewage disposal plants.

At some plants these wastes are mixed, treated with chemicals, settled, and the effluent exposed to the air in retention basis and in cascading channels before being discharged to the stream. This method appears to be adequate for some types of wastes in relationship to some stream requirements.

Color and B.O.D. can be reduced by the use of chlorine, but this increases acidity. Hydrosulfite destroys the color of some dye wastes but may increase the B.O.D. Terpenes and styrenes are blown out by aeration.

Some organic wastes are diverted to municipal disposal plants, but great care is taken to avoid the presence of such substances as acids, heavy metals, and sludges in amounts which damage installations and operations. This may involve a complicated and expensive sewer system within the plant to separate acceptable from unacceptable wastes.

Soluble Inorganic Substances

There are three types of wastes in the class of soluble inorganic substances: (1) those which are oxygen depleting, such as sulfides, sulfites, and thiosulfates; (2) those which are toxic, such as cyanides and the heavy metals; and (3) components of brine, such as sodium chloride, sodium sulfate, and calcium chloride. In the organic chemical industry, the treatment problem for these wastes is usually complicated by the presence of organic substances. In no case is it possible to destroy these substances completely, as is the case for some organic substances. Any method of treatment may leave a residue of equal amount requiring disposal.

Sulfide, sulfite, and thiosulfate liquors are being treated chemically, biochemically, and by diversion to municipal disposal plants. Chemical and biochemical treatment leave sulfates in solution and, in some cases, depending on composition and conditions, sulfur in suspension. Hydrogen sulfide and sulfur dioxide may also be released by acid and these may require treatment to avoid atmospheric pollution. Discussion of the interesting and significant chemistry and biochemistry of these processes is not within the scope of this paper, but it should be noted that chemical and biochemical treatments are expensive. Diversion to municipal disposal plants also may be very expensive if a charge is made for chlorine demand.

Cyanides are destroyed by treating with acid to give hydrogen cyanide, which is burned or released to the atmosphere in isolated areas; by conversion to thiocyanate; by treatment with lime and sulfur, or with chlorine, to give cyanate or ammonia and car-

bonate. Preference is now given to chlorination. Investigations are being directed toward precipitation of heavy metals and recovery for re-use or disposal on dumps.

The presence of iron salts in the stream is generally regarded by regulatory bodies as being objectionable because of the dark color due to the ferrous sulfide resulting from the reaction of iron with the hydrogen sulfide formed from sulfates under anaerobic conditions. As the presence of iron salts prevents release of hydrogen sulfide, which has an objectionable odor, consideration can well be given to deferring diversion of iron salts from the stream until the concentration of oxygen depleting substances has been reduced and the stream contains dissolved oxygen.

Brines are generally ponded indefinitely or for release during periods of high stream flow.

Inorganic Acids

Large quantities of inorganic acids, principally sulfuric, hydrochloric, and nitric acids, are produced as by-products of the chemical industry. Although corrective methods are relatively simple as compared with those for some of the other wastes, as a whole, they involve some very difficult technical problems and incur large expenditures. Possibilities for reducing the amounts are strictly limited, as these substances are essential parts of the manufacturing processes and recovery for use is not generally profitable because they are too dilute and highly contaminated with other chemicals.

Corrective measures for most of these wastes consist of neutralization with the commercial grades of limestone, quick lime, calcium hydroxide, caustic soda, sodium carbonate, and by-product alkalies. Which of these neutralizing agents is used depends on several conditions such as the kind of acid, the amount and strength of the acid, the rate of production, the restrictions as to space and time, the source of the material, and the extent of neutralization required. It should not be thought that use of waste alkali is free of cost. Even if there are no charges for materials, costs are incurred for installations and operations related to transportation and use.

Where space is available (usually several acres), ponds are provided for collecting, mixing, and neutralizing the larger quantities. The neutralizing unit is provided with a recording and controlling pH meter. One of the larger plants neutralizes 20 m.g.d. of effluent in this manner by use of by-product calcium carbonate slurry pumped from another plant about 1 mile away.

The acid liquors sometimes contain suspended matter and give sludges of calcium sulfate as the result of neutralization, as well as precipitates of other components which are not soluble in the neutralized liquor. These sludges sometimes interfere with the neutralization process and become disposal problems.

Those plants which do not have space for these installations run the neutralizing agents into the plant sewers. For several years, one of the larger companies fed dry lime into mixers which form a slurry before going to the sewers. In this case the commercial grade of calcium hydroxide, the most expensive grade of lime, was used to effect quick neutralization. The rate of reaction for ground limestone is too slow under these conditions. The amount required was determined by pH tests at the pump intakes for cooling water taken from the receiving stream near the sewer outlets. An average of 1,000,000 lb. per month was required for several months of each year during low stream flow. Recently, by-product calcium hydroxide slurry from the manufacture of acetylene has been substituted. The problem overcome to make this possible was

economical conversion of this material, which had settled compactly in ponds, to a slurry which could be pumped. The slurry is hauled about 10 miles in tank wagons. The cost is somewhat less than for commercial lime, but a big advantage is elimination of skin irritations due to lime dusts.

Obviously, substantial costs for installations and operations, as well as for material, are incurred by neutralization of waste acids. There are, however, monetary returns (related to reduced corrosion of equipment) to those who use the receiving waters as a process coolant or for condensing purposes.

Alkaline Wastes

Alkaline waste problems, although not so widespread as those for inorganic acids, soluble organics, and inorganic substances, are still perplexing to some companies. Alkaline wastes are needed for neutralizing waste acids, which are produced in larger amounts, and are used in this connection whenever practicable. In some cases, use of a commercial grade of alkali is less expensive because of handling and transportation costs.

The pollution problem for waste alkali is not always limited to alkalinity. Sometimes the more objectionable characteristics are due to the presence of other substances. One company passes a lime liquor through screens and a thickener to remove these other substances. The liquor is then treated with flue gas to convert calcium hydroxide to calcium carbonate, which is settled in another thickener. The slurry is dewatered on a filter and hauled to a dump.

Other Wastes

Tars and oils are separated in process equipment, or are skimmed from collecting basins. One of the greatest problems is due to formations of emulsions, which are difficult to break. Flotation, detergents, and supersonics are being investigated for this purpose. In some cases, tars and oils are treated further and used as fuel oil. Where this has not proven successful they are buried, ponded, or burned as wastes. Burning is sometimes very destructive to the incinerator because of the presence of other substances.

The first problem encountered for many insoluble and undissolved wastes is separation from process liquors. Screens, filters, centrifuges, tanks, and lagoons are used for this purpose. Settling operations require subsequent dewatering of the sludge by mechanical methods or on drying beds. The final place of disposal is the lagoon or dump.

Related Organization and Program of the Chemical Industry

The chemical industry as a whole is organized to study and solve this problem for its wastes in relation to stream pollution under the Stream Pollution Abatement Committee and subcommittees of the Manufacturing Chemists' Association of the U. S., Inc. The present membership of the main committee is comprised of R. W. Hess, Chairman, National Aniline Div., Allied Chemical & Dye Corp.; W. N. Watson, Secretary, Manufacturing Chemists' Assoc. of the U. S., Inc.; H. G. Cooke, Eastman Kodak Company; Lyman Cox, E. I. duPont de Nemours & Co.; I. F. Harlow, The Dow Chemical Company; R. E. Lester, American Cyanamid Company; H. D. Lyon, Carbide & Carbon Chemicals Corp.; E. T. Roetman, American Viscose Corp.; L. W. Roznoy, Celanese Corporation of America; and G. A. Yocum, Monsanto Chemical Co. Each member of this committee serves as chairman of a sub-committee, which plans and executes the details of the program as related to a specific class of waste. The aim of these committees is primarily one of sound and effective coordination of application by individual member companies.

Broadly stated, the program is to help the chemical industry understand all phases of its complex waste problems in relation to stream pollution, and to aid in eliminating harmful pollution. More specifically, in this connection, the program aims to:

1. Acquaint the industry with the nature of stream pollution.
2. Study and make recommendations as to standards and criteria for effluent and streams.
3. Provide opportunities for exchange of technical information on waste treatment.
4. Direct attention to the possibilities of altering productive processes to minimize pollution.
5. Emphasize the importance of recovering materials of value, even though unprofitable, to help pay the costs of pollution abatement.
6. Encourage the establishment of institutional fellowships for study of the problem.
7. Help individual companies organize sound and effective programs.
8. Encourage cooperation with regulatory bodies.
9. Keep industry posted as to the present nature and trends of anti-pollution laws and regulatory procedures.
10. Integrate the program for the chemical industry into a national program for all industry through liasion with other industries.

In summary, the principal accomplishments during the past two years are as follows:

1. A conference of representatives of member companies was held in New York City early in 1947 to discuss legal, public relations, and technical aspects of the problem. One day of this conference was given to visiting the waste treatment plant of the Calco Chemical Division, American Cyanamid Company.

2. A 2-day conference of representatives of member companies was held in New York City early in 1948 to exchange technical information on the problems for each type of chemical wastes grouped under the following classifications: soluble organic substances, soluble inorganic salts, inorganic acids, phenols and taste producing substances, tars and tarry substances, oils and oily substances, alkaline wastes, and insoluble and undissolved substances. This conference was opened with discussions of the polluting effects of each class of wastes by members of the main committee during the first half day. This was followed during the next 1½ days with 7 consecutive sessions for the exchange of technical information on treatment methods for the above classes of chemical trade wastes. At the dinner meeting the group was addressed by a prominent representative of regulatory bodies. The interest in this conference was so intense that many volunteered to serve on permanent subcommittees which were set up for making arrangements to continue and elaborate on these exchanges of information. Much of the information on corrective methods given in this paper was disclosed at that meeting.

3. A manual, "Organization and Method for Investigating Wastes in Relation to Water Pollution (W–1)," was prepared and distributed widely by the M.C.A.

4. Reprints of a "Bibliography on Wastes from the Chemical Industry in Relation to Water Pollution," prepared by the Chairman of the main committee, was widely distributed by the M.C.A.

5. Data on problems, expenditures, and programs of the chemical industry for abatement of pollution were collected, studied, and integrated into the general program.

6. A series of 6 meetings was held by sub-committees during December, 1948, to exchange technical information on abatement of stream pollution.

Related Organization and Program Within Individual Companies

Suggestions for company organization and a program to investigate wastes in relation to stream pollution are outlined in M.C.A. "Manual W–1." The National Aniline Division, Allied Chemical & Dye Corp., furnishes an example of an actual organization and program within the general scope of that outline, as follows:

Each year a Pollution Research Program, including recommendations by all technical departments, is prepared by the head of Pollution Research and approved by the management. This program permeates the entire organization. It includes specific projects, not only for the disposal of wastes, but also for the modification of established processes and the development of new processes to minimize pollution.

This program is centralized in the Pollution Research Group, which is comprised of specialized personnel and is provided with a laboratory having all equipment required for sanitary analyses. It determines pollution loads in individual wastes at their sources, in mixed wastes at sewer outlets, and in the receiving stream. This group also makes studies of treatment methods that do not come within the scope of knowledge and experience of other plant personnel.

Investigation and development of corrective measures involving process changes and treatment methods that come within the technology of the industry's production are assigned to the Chemical Research, Engineering Research, Engineering, and Operating Improvement Departments. All proposed new processes are reviewed by a committee to make certain that attention is given to minimizing pollution in the research and development stages, and all process descriptions include a tabulation of waste volumes and their components as far as known. All instances of equipment replacement are reviewed by the Pollution Research Group to make certain that no established provisions for pollution abatement are omitted and to consider the possibility of including other provisions in this connection. All construction expansions are reviewed by the same group to make certain that provisions are included to minimize pollution and to formulate for other wastes measures aimed at elimination of equivalent increases in pollution by expansions which are less amenable to correction.

The company works closely with local and State authorities in advancing the suggested program to reduce and hold the pollution load discharged to the Buffalo River at a fixed level.

The annual programs, involving all departments, are prepared, coordinated, and executed with the advice of a prominent consulting expert on wastes and stream pollution, under supervision of a pollution research head who has had some 30 years experience in research and development of chemical processes and production, 11 years of which includes experience with the stream pollution problem. Approval of the program by the management places responsibility and authority for execution on the head of the Pollution Research Department, and responsibility for full cooperation on all departments involved.

Acknowledgment

The author gratefully acknowledges the cooperation and assistance in the preparation of this paper given by representatives of M.C.A. member companies; the members of the M.C.A. Stream Pollution Abatement Committee given above; Dr. F. W. Mohlman, consultant and chief chemist of the Sanitary District of Chicago, with whom he has worked for many years on this problem; and personnel of the National Aniline Division of the Allied Chemical & Dye Corporation including, especially, Mr. C. J. Carney.

WASTES FROM CHEMICAL MANUFACTURING—A DISCUSSION

By Thomas J. Powers

Waste Disposal Division, The Dow Chemical Company, Midland, Mich.

Dr. Hess has concisely summarized the present position of the chemical manufacturing industry with respect to water pollution control. One of the most significant parts of his paper is the report on the activities of the Pollution Control Committee of the Manufacturing Chemists' Association. I have personally seen the change in this Committeee from a group whose main interest was pointed toward the legal side of pollution to a group actively promoting organization and research leading toward abatement of pollution by the industry. The Committee is to be complimented on its accomplishments.

It is of great interest to note that this industry intends to study the receiving water to determine what corrective measures are needed. Preliminary studies apparently have revealed that present methods of analyzing wastes do not give a true picture of the effects of wastes on the receiving water.

The B.O.D. test is a useful tool in measuring pollution. Used properly, it can tell many things concerning the relative strength, the toxicity, and the treatability of a waste. The industry does object, and very strongly, to the test as a standard for industrial effluent or for receiving water, and would question the value of empirical formulas based on the B.O.D. test to determine how much treatment is necessary.

In speaking of testing procedures, it may be interesting to note to what lengths a chemical plant may go to determine just what compounds are present in waste waters containing reaction compounds from many different processes. A small carbon tower is set up (say, 2.5 lb. of granular carbon) and waste water is pumped to it until, by oxidation test, the carbon is practically saturated. Composite samples of both influent and effluent are saved for analysis of one organic component. The carbon is air dried, extracted with acetone, then extracted with carbon tetrachloride or ethylene dichloride. The extract solvent is slowly boiled off and the residue is micro-fractionated. Perhaps 14 fractions are obtained. These fractions are redissolved in carbon tetrachloride, the components being determined by infra-red spectroscopy. Factors for the efficiency of the activated carbon extraction and re-extraction are applied so that the components are expressed as parts per billion of original waste water.

The industry wants to point out that any standards set on effluents or receiving streams should be scientifically and economically sound.

In speaking of corrective measures, Dr. Hess has warned that very little profitable recovery of wastes may be expected in the chemical industry. It is hoped, however, that some reduction in wastes may be effected by modernizing and altering some processes. Purification of raw materials can, in some instances, considerably reduce process wastes.

Emphasis should be placed on the warning that exhaustive studies should be made before a chemical plant is forced or allowed to use a municipal sewerage system. One municipality planned to force a chemical plant to pump extremely complex wastes to a very simple treatment works. The civic leaders may not be expected to know better, but certainly the consulting engineers should recognize the dangers in such a situation.

The alkaline oxidation of cyanide has been mentioned. This process holds great promise for the elimination of some very odorous and toxic organic compounds. One chemical company is now operating 5 chlorine oxidation plants, 3 being acid and 2 alkaline.

Processes for the elimination, adsorption, extraction, or oxidation of many organic compounds can be worked out and applied by the chemical industry. Suspensions and emulsions can be handled, but the dissolved inorganic salts resulting from manufacturing processes or from treatment of wastes will continue to present a problem. The industry must be allowed to dispose of the salts of hydrochloric acid and sulphuric acid by controlled dilution to surface waters.

The increase of dissolved solids in a surface water does place an economic burden on the water user. On the other hand, consider the economic burden placed on whole areas of our country if industry is not permitted to develop the natural resources of those areas. Great strides are being made in pollution control, but care should be exercised not to overstep the bounds of reason to the point where industry is throttled and new industry is kept from natural development.

ELECTROPLATING WASTES SURVEY

As part of a project to correlate and extend research on wastes from the electroplating industry in the United States, a committee of the American Electroplaters' Society in 1948 sent questionnaires to 255 sustaining members of the Society. Of the 106 replies received, 84 were from firms conducting plating operations.[1]

The survey indicates that in the 84 plants responding the types of plating performed are as follows:

Brass	31%
Cadmium	54%
Chromium	73%
Copper	79%
Cyanide Copper	74%
Acid Copper	19%
Lead	13%
Nickel	83%
Silver	40%
Tin	31%
Zinc	50%

Some plants also listed, in addition, such other operations as: cobalt, gold, palladium, and rhodium plating; anodizing, aluminiting, parkerizing, bonderizing, cronak processing, etc.; as well as degreasing and bright dipping.

Cleaning processes included on the questionnaire showed the responding plants using the following:

Acid pickling	81%
Ferrous	60%
Nonferrous	48%
Alkali cleaning	86%

The means of disposal used by the 84 plants are: 61 (73 per cent) to sewers, 25 (30 per cent) to streams, and 4 (5 per cent) to dry wells. These figures add up to more than 100 per cent because several plants use more than one means of disposal.[2]

[1] C. F. Gurnham, "Plating Activities in the United States." *Plating* **35**, 11, 1121 (Nov., 1948).

[2] C. F. Gurnham, "Waste Disposal Studies." *Plating* **36**, 2, 154 (Feb. 1949).

A HIGH RATE TRICKLING FILTER PILOT PLANT FOR CERTAIN CHEMICAL WASTES *

By B. W. Dickerson

Sanitary Engineer, Hercules Powder Co., Inc., Wilmington, Del.

The Mansfield Plant of Hercules Powder Company is engaged in the manufacture of various types of synthetic resins. It is located at the extreme north end of the town of Mansfield, Mass., beyond the installed limits of the municipal sewerage system. The Rumford River, which is a small stream having its origin in the Town of Sharon to the north, flows past part of the plant property. As would be expected, the plant sewerage system was installed to discharge into the river.

During the fall of 1946, a waste disposal study was inaugurated at the plant in an effort to reduce pollution of the Rumford River. The plant wastes, in addition to large quantities of uncontaminated cooling water, contain varying amounts of rosin and resin oils, dilute formaldehyde, pentaerythitol, sodium formate, organic acids, and sanitary sewage. All the liquid wastes are on the acid side, having pH values dropping below the methyl orange end point. With the exception of the sanitary sewage, all are in solution. The oils are partly in suspension and partly in emulsion, depending on process operations.

As the first step in this program, a septic tank was installed to treat the sanitary sewage. It was felt that any biological treatment processes that might be developed for the plant wastes would probably require sanitary sewage to function properly and, by removing the suspended solids, the effluent could be discharged to the treatment plant without trouble. The septic tank effluent was chlorinated, using sodium hypochlorite as the agent.

A study of the various plant wastes was made to determine rates of flow, volume per day, composition, and B.O.D. In this work the cooperation of the Massachusetts Department of Health was most helpful, as plant laboratory personnel were unfamiliar with B.O.D. technique and the constant temperature units for this work were not available at the plant laboratory.

Toxicity Affects B.O.D. Values

It might be well to point out one of the problems encountered in determining the B.O.D. of toxic wastes. With toxicity present, the 5-day B.O.D. values will increase with increasing dilution until beyond the toxic limit, after which consistent results will be obtained. These then are the proper values to use. It will not be possible to obtain 50 per cent depletions every time and the technician will be required to use his best judgment, with depletions as low as 18 per cent and as high as 75 per cent. B.O.D. may be a valuable tool, but there is a great deal more to be learned about it when measuring industrial wastes.

Many of the processes require high vacuum during the cycle and steam jets equipped with barometric condensers are used as vacuum pumps. Such devices contaminate the cooling water required for operation and, although they reduce waste concentration, they increase the total volume of contaminated water to be handled.

* Presented at Twentieth Annual Meeting, New England Sewage Works Associations; Newport, R. I.; Sept. 9–10, 1948.

As a result of the survey it was found that the plant had a total B.O.D. load of approximately 2,000 pounds per 24 hours, with B.O.D. values ranging from 300 to 10,000 p.p.m. and formaldehyde concentrations up to 5,000 p.p.m. The total flow, including cooling water, was approximately 0.5 m.g.d.

Stream flow and dissolved oxygen data obtained on the Rumford River for dry weather flows indicated a total allowable loading of 75 pounds of B.O.D. per day. As there were others who had riparian rights on the stream, it was felt that Hercules would be entitled to 30 pounds B.O.D. per day allowable discharge. This meant practically complete treatment of the plant wastes and, to add to the problem, there was nothing in published literature or in known methods for treating such wastes. Thus, there arose the necessity for developing methods of treatment or disposal.

Several Methods Tried

In considering the various possibilities of disposal, the first that came to mind was lagooning. The plant property is long and narrow. Manufacturing and warehouse buildings occupy practically all of it, thus eliminating any possibility of such a holding basin inside the fence. A careful study of the U. S. Geological Survey map of the surrounding countryside was made for possible sites. Two locations finally were selected. These would have been satisfactory, provided the land could be purchased, unfortunately, however, the properties were not for sale so this method had to be abandoned.

Next was the possibility of discharging into the Mansfield town sewerage system by pumping to the nearest system manhole, providing the capacity was sufficient to take the plant waste load and the existing treatment processes could handle the wastes. The town disposal works is comprised of an Imhoff tank, a standard rate trickling filter, and sludge drying beds. The volume of flow to the plant varies from 0.25 to 1 m.g.d., depending on weather conditions, as there is considerable infiltration during rainy periods.

To employ such a method of disposal, the waste volume would have to be reduced to a minimum to prevent overloading the system, thus requiring segregation of the contaminated wastes and the uncontaminated cooling water, with discharge of the latter directly to the river. Surface type intercondensers were installed in place of the barometric units on the several jets, thus reducing appreciably the volume of these wastes. By this method, the waste volume requiring treatment in the municipal system could be reduced to about 50,000 g.p.d. This gave dilution by the sanitary sewage in the ratio of 6:1 to 20:1. The $64 question was whether at low dilution (6:1) the wastes would not be toxic to the low rate trickling filter in the town plant.

A pilot plant trickling filter operated for a period of time at the same rate of application as the town unit and supplied with a mixture of the two wastes at the minimum dilution would supply the answer. At that time the plant had no such unit. At this point, through the cooperation of the State Department of Health, this portion of the study was transferred to the Lawrence (Mass.) Experiment Station. A small trickling filter was placed in operation on a minimum dilution mixture of sanitary sewage and the plant's industrial waste. The unit used was 10 in. in diameter and had 6 ft. of stone. It was operated at a 1 m.g.a.d. rate.

After a few days operation, the unit began to function and fairly satisfactory removals were obtained. These continued for about two months, after which the biological growths died completely in two days. Because the plant waste was toxic, it was believed that this factor accounted for destruction

of the bacteria; but the reason for the quick death after two months of operation remained obscure. However, because all the bacteria had been destroyed in the pilot unit and this could not be permitted at the municipal plant, phase two of the program ended.

A new study was instituted to cover chemical destruction of the formaldehyde. About every conceivable method was investigated. The net result was that chemical destruction was entirely too costly and in many cases produced an end product more difficult to handle than the original. It may be of interest to mention here that ozone treatment was investigated, and rejected on the basis of both initial cost and cost of operation. The method held some promise of destruction of the formaldehyde, but the economics were against it. Phase three was ended.

High Rate Filter Provides Answer

Inasmuch as biological treatment had functioned for two months, it was felt that this work should be re-examined for a possible answer to the destruction of the bacterial growth on the filter.

In the earlier work the fact that formaldehyde is a good tanning agent had been entirely overlooked. Could not this action on the cell walls of the bacteria have caused their death? If insoluble compounds were developed, they would cut off the organisms' only means of obtaining food. Large concentrations would show immediate effect; in small concentrations this effect might not be noticeable for a long time. It is believed that what occurred was this building up of insoluble compounds in the cell wall thereby reducing the available feeding area to such an extent that sufficient food could not be taken in through the wall to maintain life. The bacteria literally starved to death.

It is well known that on a low rate filter sloughing occurs only at intervals which would allow the above condition to develop. If the filter could be operated at a very high rate, with heavy continuous sloughing taking place, there would be no chance for this development. Instead, there could be produced a very active growth which would provide a high degree of treatment. It was felt that a pilot unit should be constructed and operated continuously at the plant to determine whether this theory was correct. The initial program was to be carried out with formaldehyde only. If successful in treating high concentrations, the feed would be changed to plant wastes to determine their possible treatment.

The filter unit selected (see Figure 1) was 10-in. diameter terra cotta pipe having 6 ft. of stone in three 2-ft. lengths. It was to be operated at a rate of 50 m.g.a.d. Sedimentation was to be short to allow maximum recycle of bacteria; 15-min. retention was provided. The tile was provided with a slat bottom, which served as support for the stone and also to elevate the bottom of the tile about 4 in. above an inclined box serving as collecting tray for the filter. This box was elevated sufficiently to provide gravity flow to the sedimentation basin. A framework of 2 by 4's provided lateral support for the tile and means for holding piping and the filter distributor. It also provided means of access to the top of the filter. The filter distributor was a 10-in. colander obtained in the local hardware store. When set level, it provided very excellent distribution over the filter stone.

Stones for the unit were carefully selected from the town trickling filter; only those with heavy growths were taken, the size varying from 1½ to 2½ in. The filter was ready for operation as soon as packed.

The sedimentation basin was designed along conventional methods and provided 15-min. retention with the filter operating at 50 m.g.a.d. This was equivalent to a volume of 6.4 gal. at a rate of 1,600 c.c. per min.

A wood tank holding about 100 gal.

was provided for holding the formaldehyde solution and, later, the composite waste. A proportioning pump was used for recycling to the filter; a duplex pump for the waste solutions.

River Water Added

For the initial operation, it was thought that some pond water or uncontaminated river water should be added to the system just ahead of the filter so there would be additional organism added and some dilution of the waste prior to filtration. A second wood tank was used to hold this supply, which was obtained from the Rumford River above any known source of major pollution.

To mix the river water and the recycled liquor, a mixing chamber was installed just ahead of the filter distributor. This comprised a piece of 2-in. pipe and 8 in. long fitted with a reducing coupling on the bottom, terminating in a ¼-in. nipple, which discharged into the colander. The two feed pipes were set to discharge into the 2-in. pipe at an angle, so that there would be tangential mixing before dropping on the colander. The arrangement proved very satisfactory.

Formaldehyde is an organic compound of carbon, hydrogen, and oxygen. It was felt that, even with the pond water addition, there might not be sufficient chemical balance for proper maintenance of biological life. The pond water was treated with the same chemicals as used in making up the standard B.O.D. dilution water; namely, potassium phosphate, ferric chloride, calcium chloride, and magnesium sulfate. In addition, it was believed that a minimum carbon-nitrogen balance should be maintained and a 25:1 ratio was provided through the use of ammonium phosphate added to the pond water.

The formaldehyde solutions had an acid pH. Therefore, they were adjusted to 7.0 with aqueous ammonia, not only to add nitrogen, but also to eliminate sodium. Sodium salts for pH correction were studiously avoided as sodium formate was formed in the reaction of the sodium with the formal-

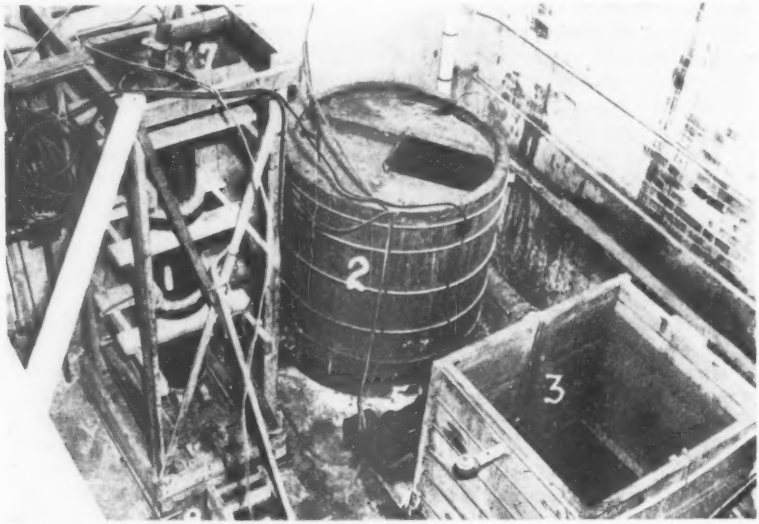


FIGURE 1.—High rate trickling filter pilot plant for treating wastes from synthetic resin manufacture.

dehyde. Bacterial studies, which had been made earlier at Lawrence, indicated this compound to be more toxic than formaldehyde.

It was believed that in using pond water for dilution some initial stabilization of the filter and system should be made with the types of organisms present in this water. The pilot plant was operated for about 10 days on pond water only, the rate of feed being 160 c.c. per min. The system was operated at the 50-m.g.a.d. dosing rate of the filter, equivalent to 1,600 c.c. per min. circulation.

Formaldehyde Concentrations Used as Criteria

After the initial operation, the pond water rate was reduced to 80 c.c. per min. and formaldehyde at a concentration of 500 p.p.m. was added at the same rate. Over a period of a month the system gradually adjusted itself and the average formaldehyde concentration applied at the top of the filter was 60 p.p.m. The average filter effluent showed 46 p.p.m., a reduction of 14 p.p.m. (29 per cent), equivalent to a removal of 0.58 lb. per cu. yd. Inasmuch as formaldehyde was the chief constituent of the waste feed, it was felt that evaluation of pilot operation should be based on removals of this component effected by the filter and system. The plant laboratory was already set up to make these determinations quickly and accurately, so this procedure fitted well into the picture. The correlation of formaldehyde and B.O.D. values then could be taken care of later when the 5-day B.O.D. period could be tolerated.

The waste feed had been piped to discharge directly into the inlet flume of the sedimentation basin, thus providing mixing and a 15-min. contact before dilution with pond water. Basin effluent samples were found to be well above the filter effluent values. This was as expected, as they reflected the addition of the raw waste. In order to be able to withdraw at a constant rate from the system at minimum concentration, a constant-head overflow was installed near the inlet end of the basin and the waste feed was relocated so that it discharged into the effluent flume. The effect of raw waste in the effluent was thus eliminated. No impairment could be discerned in the operation of the system, so this method was used throughout all the tests. Values of the effluent were slightly lower than those directly from the filter.

At the 500 p.p.m. feed, the over-all system removal was 82 per cent. If the removal on the filter is considered in relation to the total formaldehyde fed to the system, this value becomes 56 per cent instead of 29 per cent. In a small unit actual stone volume is considerably less in relation to computed volume than it is in full scale plants. An 80 per cent area value was felt not unreasonable, and the adjusted removal was 0.72 lb. per cu. yd.

After effective operation had been obtained at the 500 p.p.m. feed rate, the concentration was gradually stepped up to 1,000 p.p.m. in a period of a little over two weeks. Excellent results continued, with 30 p.p.m. being removed in the filter, thus giving an efficiency of 40 per cent. The concentration in the effluent dropped to 50 p.p.m. and the over-all system efficiency rose to 90 per cent. These results were so encouraging that the feed concentration was increased to 1,500 p.p.m. all at once. This was almost disastrous as filter effluent values increased to over 300 p.p.m. However, some growth could still be seen on the stone and there was about a 40 p.p.m. reduction through the filter, a somewhat higher value than previously. This looked hopeful, but it was not felt that a chance should be taken by continuing at the high value. Therefore, the feed was reduced to 1,200 p.p.m. and the plant was operated on this basis for about three weeks. The sys-

tem gradually stabilized. Reduction through the filter was 36 p.p.m., an increase of 20 per cent, but the system concentration could not be reduced to the low values previously obtained. The average influent concentration to the filter was 171 p.p.m. and filter effluent was 135 p.p.m.; filter efficiency was only 21 per cent and adjusted removal 1.86 lb. per cu. yd. These higher levels continued throughout the remaining tests. The over-all plant efficiency was 78 per cent.

The waste feed was again increased slowly to 1,500 p.p.m. over a period of two weeks. The system gradually became stable and the influent to the filter averaged 155 p.p.m., filter effluent 115 p.p.m., and filter removal 40 p.p.m. (equivalent to 26 per cent). Adjusted removal was 2.07 lb. per cu. yd. The system efficiency was 85 per cent.

No Improvement with Forced Air Circulation

In considering possible means of increasing filter efficiency, the use of forced air circulation was felt to hold possibilities. Therefore, the bottom of the filter was enclosed in a sheet metal housing into which a 4 in. diameter fan was connected. A good circulation of air was provided, but there was no improvement in operation.

By this time it was fairly well established that biological treatment would remove formaldehyde from waste waters in concentrations up to 1,500 p.p.m., provided 1:1 dilution was employed. In full scale plant operation the volume of pond water necessary would be difficult to obtain and costly. If it were possible to eliminate this dilution, even at an increase in recycle rate, this would be most helpful. The pond water was eliminated from the system and the rate of feed of formaldehyde was reduced to 40 c.c. per min., providing a 40:1 recycle. The plant was operated at this rate for a month. Filter influent averaged 190 p.p.m.; filter effluent, 140 p.p.m.; filter removal, 50 p.p.m.; and filter efficiency, 26 per cent, equivalent to an adjusted removal of 2.59 lb. per cu. yd. The system efficiency was 90 per cent. In eliminating the pond water, the chemical dosage which had originally been given it was added to the formaldehyde solution.

During this phase of the work, it became necessary to move the pilot equipment to allow access to some existing machinery. This necessitated a shutdown of the operation for about 8 hr., with consequent drying out of the filter. This almost proved catastrophic. When operations were resumed the formaldehyde concentration in the system rose to 650 p.p.m.; it took over two weeks to return to the earlier values. Heavy sloughing of the filter slimes occurred and it was thought that this unit had been lost, but apparently some hardy colonies survived and gradually multiplied to reseed the unit.

In continuing the experiments the waste feed concentrations were gradually raised to 1,700 p.p.m., and then to 2,050 p.p.m. Filter removals remained at 50 p.p.m. and filter effluent values rose to 215 p.p.m., with over-all system efficiencies of 90 per cent. Filter efficiency at the 2,050 p.p.m. feed was 23 per cent, equivalent to an adjusted removal of 2.59 lb. per cu. yd. There was no increase in filter removals above that obtained at the 1,500 p.p.m. feed.

During the run at 1,500 p.p.m. concentration without pond water addition, the effect of pH was studied. This was accomplished by adjustment of the formaldehyde solution with aqueous ammonia; the range from 4.5 to 8.5 was covered. It was impossible to correlate any improved operation with pH. An interesting observation throughout this run was that the filter effluent held between 6.5 and 7.5. With low pH values of feed, the effluent remained slightly below 7; as the pH was increased the effluent pH also increased, but at a lower gradient.

Samples of filter influent and effluent were taken at intervals to the Lawrence Experiment Station for B.O.D. determinations. Duplicates were analyzed at the plant for formaldehyde concentration. It was interesting to note that the 5-day B.O.D. averaged about twice the formaldehyde concentration.

Another very significant change was in the zoogloeal growth on the filter stone as the bacteria became acclimated to the formaldehyde. Originally there was a very heavy growth with a dirty gray color and some spots of green. As the work progressed, a thin, nearly colorless slime developed on the stone. It had a slight tinge of pink and the appearance was more like the mucous covering inside a freshly opened oyster. Although at no time during this period was the slime really heavy, it gave the impression of a very active film.

During the run at 1,500 p.p.m. concentration, experiments were carried out on the possibilities of lagooning the filter effluent. Two wooden trays 3 ft. by 6 ft. and providing a 6-in. depth of liquid were built and placed out of doors in an unshaded location. One was filled with the raw waste and the other with filter effluent. This experiment lasted 15 days, during which no rain fell to complicate the tests. The untreated waste increased in concentration over the test period, due mainly to evaporation. There was a uniform reduction in the filter effluent of about 14 p.p.m. per day until 10 days had elapsed. After this the reduction was about 7 p.p.m. each day. By 13 days, the concentration had dropped to 5 p.p.m. and no further reduction was detected. The formaldehyde concentration at the start was 170 p.p.m. This was a real reduction and worthy of consideration in the final plant design. The pH value was initially 6.5, but rose to 8.0 by the 13th day, at which time the formaldehyde concentration had reached 5 p.p.m.

The work to date had been on formaldehyde only. For the design of a full scale plant data covering operation on the composite plant waste would be necessary. Accordingly, a composite was made up using actual percentages of the various process wastes; formaldehyde, rosin and resin oils, sanitary sewage, miscellaneous floor washes. The same rates were maintained in the pilot system—50 m.g.a.d. and 40:1 recycle. No pond water was added, but the chemical dosage of the raw waste was maintained. This run covered a period of two months. The average formaldehyde concentration in the waste feed was 800 p.p.m.; that applied to the filter, 65 p.p.m. The filter effluent averaged 44 p.p.m., with an efficiency of 35 per cent. The system efficiency was 94.5 per cent. This concluded the investigations, as it was felt that this type of treatment would handle the plant wastes satisfactorily and a full scale plant could be designed.

During the operation on composite plant waste, the character of the slimes on the filter changed. The rather thin translucent film developed into a heavy brown growth quite similar in character to that originally developed by the sanitary sewage. This was no doubt caused by the variation in organic material from that of the straight formaldehyde.

Organic Oils Present No Filter Problem

Some qualms were felt about how well the filter would function with the rosin and resin oils present in the composite waste. Although the actual floating oils constituted less than 1 per cent, some 20 per cent of the total was in emulsion form. Throughout the whole run, there was neither indication of reduction in efficiency from this source, nor build up on the filter stone. Incidentally, this has been found to be true in another full scale two-stage

trickling filter plant where there is a large quantity of these oils. Operation after 8 months has shown neither destruction of bacteria on the stone nor oily build up. Both primary and secondary basin sludges contain sufficient oils to stop proper dewatering on a vacuum filter, even with excellent pretreatment employing lime and ferric chloride. From these observations, it is believed that this type of oil can be handled in a trickling filter plant without detriment, whereas regular mineral oils would cause fouling.

No Filter Flies

The question of filter flies also caused some concern. This pilot plant had been installed in a warm room, with temperatures as high as 95° F. During the summer and early fall the doors and windows were left open. At no time during the course of the experimental operation was there any evidence of filter flies. The original contention had been that a high rate filter application would solve the fly problem. However, in pilot studies made on powder plant wastes, with rates of 30 m.g.a.d. applied to the filter, there had been luxurious development of psychoda flies, completely disproving this theory. During the past three months of operation of the full scale plant previously discussed, at the 30 m.g.a.d. rate of application, there have been no evidence of fly formations. It is believed that with toxic wastes there will be no fly problem, even at lower filter rates.

During the last part of the run on composite plant wastes, we became interested in the possibility of phenols in some of the process wastes. Several analyses were made on the composite waste, the filter influent, and the effluent, in accordance with procedures outlined in the 9th edition of "Standard Methods." These tests showed phenols in the waste as high as 40,000 p.p.b.; filter influent, 2,000 p.p.b.; filter effluent, 1,600 p.p.b. The filter efficiency was 20 per cent; the system efficiency, 96 per cent. From other work it is known that this method will provide effective reduction of phenols in rosin wastes. This statement is qualified because there is not as yet sufficient information to make comparisons with the usual commercial phenols.

Sludge studies were made during the operation of the unit on straight formaldehyde and on composite plant waste. In both instances the volume produced was small and consisted mainly of filter sloughings. With the formaldehyde, this material was very light and flocculent, whereas that produced from the composite was heavier and denser due, probably, to the difference in character of the filter slimes. The volume produced was about the same in both cases and amounted to 0.2 cu. ft. per day. Based on a feed of 1,500 p.p.m. formaldehyde, this amounted to 0.10 cu. ft. per pound of formaldehyde; on the basis of the composite, the volume produced was 0.11 cu. ft. per pound of 5-day B.O.D. removed.

Dissatisfaction has been felt with these studies, due to the small quantities with which the work was carried on. Therefore, the figures developed have only been used in a general way, as it is felt that the final answer will have to be obtained from full scale operation.

Conclusions

As a result of these experiments certain general conclusions have been evolved, as follows:

1. The high rate trickling filter can be used to provide satisfactory reduction of formaldehyde, and organic oils and acids. The following table shows removals obtained per cubic yard for various concentrations applied to the filter.

Applied Formaldehyde Concentration (p.p.m.)	Removal per Cubic Yard (lb.)	Removal Efficiency (%)
60	0.73	29
80	1.55	40
171	1.86	21
190	2.59	26
230	2.59	28
265	2.59	23

2. It is not necessary to maintain a constant pH value at 7.0, the neutral point, as variations as low as 4.5 and as high as 8.5 will not affect operation. It is necessary, however, to hold a fairly uniform pH wherever it may be. Filter effluent pH values will be within the range 6.5 to 7.5 regardless of raw waste pH.

3. Short sedimentation periods are effective for the filter system. Where the effluent from the disposal plant must be discharged directly to a stream and no provision for lagooning can be provided, additional sedimentation is advantageous. It provides minimum B.O.D. values through additional removal of suspended material, which is primarily filter sloughings and has a high B.O.D. With lagooning, the short detention is preferable, in order that ample bacterial life can be maintained in the lagoon.

4. There is no filter fly problem with wastes of this type.

5. Although these studies were carried on with a filter application rate of 50 m.g.a.d., it is quite possible that a somewhat lower rate might be satisfactory. The important point is the maintenance of a sufficiently high sloughing rate to prevent insoluble build up in the cell walls of the bacteria.

The most important conclusions derived from this experimental work are: (1) that toxicity is only relative; (2) that by proper application, bacteria can be developed which will thrive in the so-called toxic mediums and provide satisfactory removal of organic material; (3) that thorough study of the problem and operation of a pilot plant sufficiently long for stable operation is absolutely essential; and (4) that the use of high rate filters should open further channels for the solution of industrial waste treatment problems.

Based on these studies, a full scale treatment plant has been designed and built and is now in initial operation. However, there has not as yet been sufficient time to secure any real operating data.

Acknowledgments

We wish to take this opportunity to express our appreciation for the splendid cooperation and assistance given by Messrs. Weston, Wright, and Taylor of the Sanitary Engineering Department, and Mr. McCarthy of the Lawrence Experiment Station, all of the Massachusetts Department of Public Health.

MAKE YOUR HOTEL RESERVATIONS FOR THE BOSTON CONVENTION

The Hotel Statler at Boston, headquarters for the Twenty-Second Annual Meeting of the Federation in October, will be able to accommodate all out-of-town registrants.

Requests for room reservations should be addressed directly to the hotel. Note that the technical program will open on Monday morning, October 17, and will close at noon on Thursday, October 20.

WRITE NOW FOR YOUR RESERVATIONS!

WASTE CONTROL IN A COKE PLANT *

By K. N. Bundy and P. E. Jordan

Assistant Technical Advisor and Technical Advisor, respectively, Wheeling Steel Corporation, Follansbee, W. Va.

The heavy concentration of industry and the resultant concentration of population along rivers has created serious pollution problems for industries and municipalities that must depend upon such rivers for drinking, industrial, and recreational water. In particular, the large quantities of phenolic and other high B.O.D. wastes from by-product coke plants heavily tax the self-purification powers of the receiving rivers. In addition, the extreme sensitivity of the palate to the chlorophenol compounds brings considerable public attention to these wastes. Thus, a by-product coke plant offers an excellent example for pollution definition and abatement, and the methods of recording and reporting the information.

A waste cannot usually be adequately defined at a sewer outfall; the components of an effluent must be traced to their sources. To do this some knowledge must be had of the basic operations in the plant. It is not the purpose of this paper to tell how a coke plant is to be operated. It is well, however, briefly to consider a partial flow sheet that emphasizes the waste producing operations. Such a flow diagram for the Follansbee, W. Va., plant of the Wheeling Steel Corp. is shown in Figure 1.

Origin of Wastes

The heart of the plant is the battery of ovens in which coal is carbonized in the absence of air. Three products result from carbonization—coke, gas, and an aqueous liquor containing heavy tar in suspension and certain ammonia compounds in solution. The hot gas passes through the primary cooler where it is cooled indirectly with water circulated through tubes. Phenol, ammonia, light tar, and most of the water is condensed here and is pumped to the tar decanter tanks. The cooled gas next passes through exhauster engines, is reheated, passes through precipitators that remove the remainder of the tar in a strong electrostatic field for pumping to the decantation system, and passes through saturators containing 6 to 12 per cent sulfuric acid. The gas, having been reheated before entering these saturators, evaporates enough water so that all the waste water from the vicinity of this equipment may be pumped back into it, thus keeping a high acid waste from the sewer.

From the saturators the gas passes through a tower where it is cooled by direct contact with water sprays, naphthalene and other higher boiling oils and water-soluble constituents, such as hydrogen sulfide, hydrogen cyanide, and phenol, being dissolved in the cooling water and carried away. The gas then passes through packed towers where it is scrubbed with a cold, high-boiling petroleum oil, which absorbs the heavier hydrocarbon oils from the gas. The clean gas is then picked up by booster engines, about 40 per cent of it being used for heating the ovens, the remainder being sent to the steel plant as fuel.

At the ovens, red hot coke is discharged by rams and taken in a car to a quenching tower, where it is cooled quickly by sprays of the waste water from the final cooling tower.

The aqueous liquor from the coal

* Presented at Second Annual Meeting, West Virginia Sewage and Industrial Wastes Association; Clarksburg, W. Va.; Oct. 1, 1948.

carbonization is collected in a decanting tank, where the tar settles to the bottom and is pumped to storage tanks. The liquor—known as ammonia liquor—is then taken to storage tanks, from which it is fed to the ammonia recovery system. This system consists of three sections—a "free" ammonia still, a phenol recovery tower, and a "fixed" ammonia still. By the use of direct steam the first, or "free" section, removes free ammonia and some phenol, and decomposes and removes the more loosely associated ammonium compounds, such as carbonate, bicarbonate, cyanide, sulfide, and the polysulfides, for return to the gas stream. The ammonia liquor is pumped from the bottom of the free still to the dephenolizing tower where about 90 per cent of its phenol is removed by steam. This vapor is passed through caustic soda solution for phenol removal, then through the ammonia liquor, and then recirculated. The dephenolized liquor is returned to the so-called "fixed" leg of the ammonia still, where it is mixed with milk of lime and steam-distilled to decompose the ammonia chloride, thiocyanate, ferrocyanide, sulfate, sulfite, thiosulfate, and other of the more stable ammonium salts. The gaseous ammonia returns through the free leg to the gas system and the liquor from the still goes to the sewer.

In the light oil system the enriched wash oil is pumped from the gas scrubbing towers to a still where the light

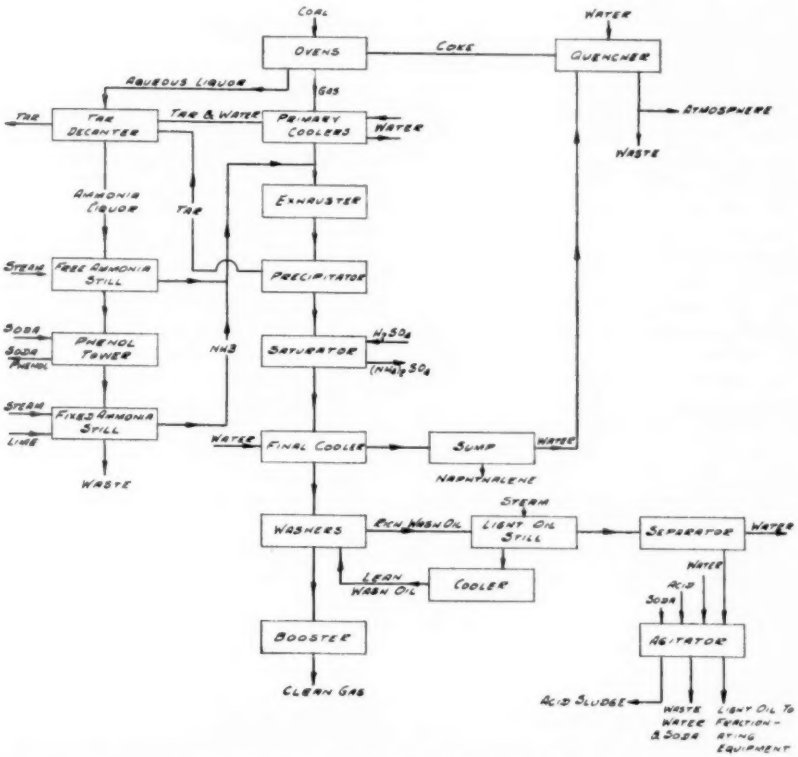


FIGURE 1.—By-product coke plant flow diagram.

oil is removed from it by direct steam distillation. The hot wash oil is cooled and returned to the scrubbing towers. The light oil and steam from the top of the still are condensed and separated, and the water is drained to the sewer. The light oil is topped and then washed successively in an agitator with strong sulfuric acid, water, and caustic soda to remove unsaturated compounds. The washed light oil then passes to fractionating equipment where it is separated into pure benzene, toluene, and xylene.

Amounts of Wastes

Reconsideration of the flow diagram from the standpoint of waste products shows that a large proportion of the water used is for indirect cooling and only serves to lower the concentration of other pollutants. This includes water used in the primary coolers, wash oil coolers, and in the condensers on the benzol fractionation equipment. The most serious waste is that from the ammonia still. Ammonia liquor is produced at the rate of 20 to 25 gal. per ton of coal coked. This is augmented by about 10 per cent in the ammonia stills by heating steam. Although about 90 per cent of its phenol has been removed, it still contains some 300 p.p.m. of phenol, about 1 per cent of calcium chloride, plus other organic and inorganic compounds that have high chemical and biochemical oxygen demands. The saturators are not a source of pollution.

The water from the final cooler contains about 200 p.p.m. phenol, about 100 p.p.m. of emulsified naphthalene, and various other inorganic compounds of the same nature as those found in the ammonia liquor. The water is collected in a sump, where the naphthalene is recovered from the surface. The water, if sent to the sewer, would be a much larger source of phenolic waste than the ammonia still waste, as there are about 180 gal. of final cooler water required per ton of coal. However, since 1941 this water has been used for quenching coke, thus considerably reducing the phenol. The water from the quenching station would be a potential source of suspended inert solids if not allowed to settle before disposal.

The remaining source of pollution is the light oil and benzol plants. Here the water separated in the light oil condensation system, although free of solids, contains considerable dissolved organic materials—a source of B.O.D. The acid sludge, although not a direct stream pollutant, is a troublesome waste and is disposed of by burning. The waste water and soda wash from the agitator go to the sewer, and although small in volume are oxygen consumers. The spent soda wash contains sodium sulfite.

Process Alterations to Reduce Wastes

Consideration can now be given to past alterations in the basic operations in the plant to reduce waste. The history of pollution abatement at the Follansbee Coke Plant dates back to 1930, when one of the first Koppers vapor recirculation systems for the removal of phenol from ammonia liquor was installed. This one piece of equipment keeps about 1,200 lb. of phenol per day out of the river; and had it not been for final cooler water, the phenol in the plant effluent would not have been of too much consequence. The plant was, however, one of several phenol contributors in the area and a further reduction of all such contributors was desired.

A survey made in 1941 showed that 76½ per cent of the phenol entering the river came from the final cooler water, 18 per cent from the ammonia stills, and 5 per cent from the light oil condensers. As final cooler water is not too objectionable for quenching coke, this was recommended and tried.

After two months of quenching with this water, another survey was made. The results showed that the final cooler water going to the quenching station

had an average of 188 p.p.m. phenol, whereas water from the quencher had 77 p.p.m. Considering that much of the water is lost as steam at the quencher and as moisture in the coke, this was a considerable reduction of phenol. Permanent arrangements were made for quenching with final cooler water.

During the war, pollution abatement, while not forgotten, was pushed into the background by more important things. However, in 1946 the State Water Commission requested a complete semi-annual analysis of our sewer effluent. Fortunately, the plant has only one outfall into the river. It was still somewhat of an undertaking, however, as no previous attempt had been made to measure flow at the sewer.

Even though the greater part of plant operation is continuous, grab samples were not considered representative and it was decided that 24-hr. continuous samples would be taken for 7 days. The first samples were taken by hand every 20 min. This required constant attendance at the sewer and it became desirable to devise an automatic sampling system. For this purpose a 7-g.p.h. pump was installed so that 8-hr. samples could be collected in a drum. The pump intake consisted of a pipe immersed vertically in a turbulent section of the stream and drilled with holes so that a cross-sectional sample would be taken.

For flow measurement, a rectangular weir was used. During the first sampling period the height of water above the notch was measured by a U-tube, a reading being taken every 5 min. When the sampling pump was installed a continuous water level recorder also was installed. This consisted of a small air pump, mounted on the water pump base and run from the same shaft, used to keep a small stream of air bubbling through a vertical section of pipe extending into the stream to the level of the weir notch. The pressure necessary to keep this pipe filled with air was recorded on a pressure recorder calibrated in inches of water.

The analytical methods used conformed, as much as possible, to A.P.H.A. standard methods. There has been considerable criticism of the B.O.D. test for industrial wastes, but the writers believe that it gives fairly consistent results for coking wastes.

Form for Reporting Data

After the effluent had been measured and analyzed, it was desired to put the information into a form that would give an over-all picture of pollution data to management and to the State Water Board. The form used for presenting this data (see Figure 2) originated at the Yorkville, Ohio, plant of the Wheeling Steel Corporation. It not only records sewer flow and analysis, but also the characteristics of the water supply and its distribution throughout the plant. For the sake of brevity, only three days of sampling are shown, but the diagram is similar to those sent to the Water Commission after the semi-annual surveys. The flow figures listed are in gallons per day; the analytical results, in p.p.m.

The first thing desired is the nature of the water supply. Because a year round supply of low temperature cooling water is desired, wells are used rather than river water. Note the importance of analyzing the water supply: two wells show a considerable oxygen demand. These wells are found to have been contaminated, a condition not previously suspected. The cause was determined and the condition is being remedied.

Each well is equipped with a positive displacement meter so that accurate measurements are available on the supply of water to the plant. Water from the wells is pumped to a sump, the composite analysis listed being that for water going to this sump. The flow quantities listed are the sums of the individual meter readings. When plant demands exceed well production

some service water is pumped from a steel plant on the Ohio side of the river, this water also being metered and going to the sump. The river pump is for emergency only.

Moisture in the coal is the major source of the ammonia liquor. This is determined daily in the laboratory. Moisture condensed from the gas at the final cooler may be calculated, knowing the temperature drop and assuming the gas to be saturated.

Water from the sump is distributed to the various pieces of equipment in

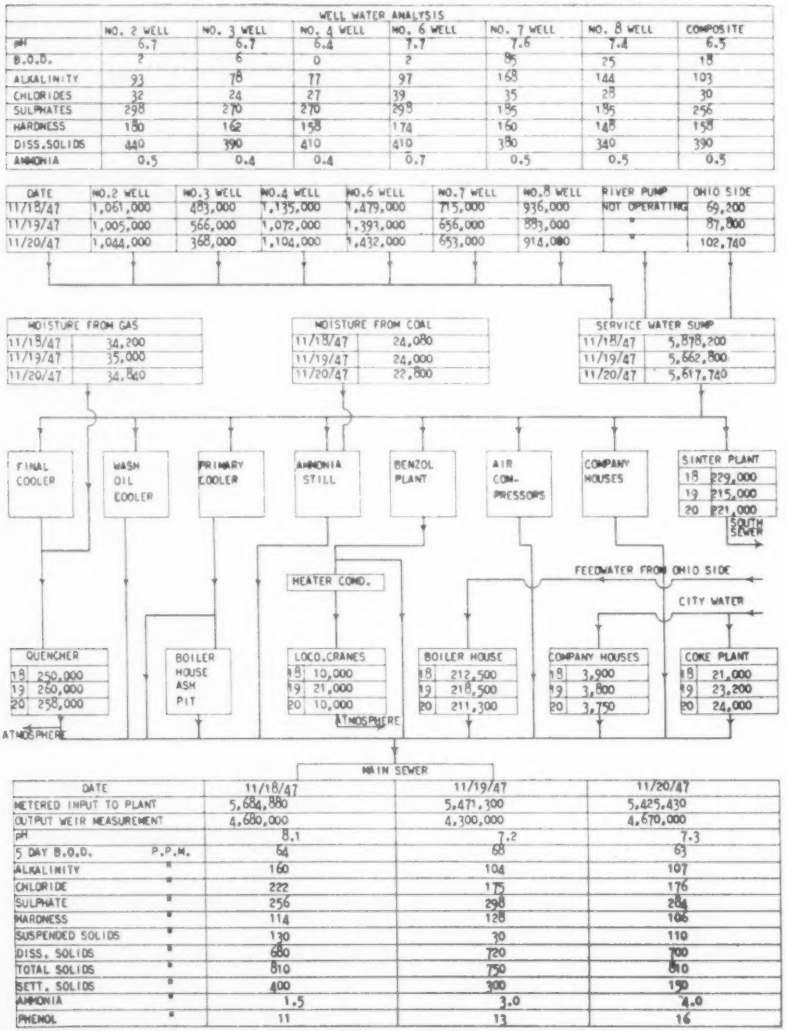


FIGURE 2.—Coke plant water distribution and sewer analysis.

the plant. It goes to the final cooler, wash oil coolers, primary coolers, to the ammonia still in the form of milk of lime, to the benzol plant as condenser water, to the air compressors for cooling, and to a group of company houses nearby for flushing toilets. Metered water is also furnished to a nearby sintering plant, which has its own sewer outlet.

As previously mentioned, final cooler water is used for quenching coke, part of it going from the quenching station to the sewer and part to the atmosphere as steam. About one-third of the primary cooler water is used to flush out the ash pits below the boilers, resulting, incidentally, in some inert suspended matter in the sewer. Some condensed steam from heaters at the benzol plant is used for feedwater on locomotive cranes, this water eventually going to the atmosphere. Metered feedwater to the boiler house is supplied by the steel works across the river. Drinking water for the coke plant and the company houses is supplied by the City of Follansbee.

The effluents from all the equipment, as well as domestic waste from the plant and houses, are collected in one main sewer. The analysis for this sewer is reported for each day, as is also the measured flow at the weir. Also recorded is the sum of the metered inputs to the various parts of the plant. The difference represents losses to the atmosphere in the plant.

It is evident from a comparison of sewer and service water analysis that the impurities added to the water are materials causing B.O.D., chlorides, suspended and dissolved solids, ammonia, and phenol. Note that hardness is decreased somewhat.

Further Pollution Reduction

The easiest and cheapest time to institute changes in operation and waste disposal is during an expansion program. In rebuilding and expanding the coke plant, the opportunity is being taken to make all changes that will decrease pollution from the plant. The expansion program necessitated installation of new by-product equipment of sufficient capacity to handle by-products from both old and new ovens.

The biggest improvement is to be a recirculation system for the final cooler. A two-section tower will use mostly recirculated water for cooling the gas, only a small amount of water from this cooler being used for quenching. Thus, phenol from this equipment will be eliminated. Water from the light oil separators will be used for make-up water in the recirculation system. Inasmuch as this is distilled water, it will prevent dissolved solids build-up in the system. At the same time a troublesome waste will be eliminated from the sewer.

The only remaining source of phenol will then be the ammonia still waste, which will be improved by increased efficiency of operation in the dephenolizing tower.

During the early part of the construction period, the sewer system was changed so that domestic sewage could be segregated from industrial waste, if and when that becomes necessary.

In closing, it should be emphasized that the steel industry as a whole has made a determined effort since 1930 to reduce its contribution to stream pollution. In doing this it was first necessary to define the nature and volume of the pollutants being discharged to the river. This paper has described the methods adopted and the results obtained in studies at one coking plant connected with the industry.

Acknowledgment

The authors wish to thank Mr. R. A. Swift, Superintendent of the Follansbee coke plant, and Mr. R. B. Smith, Special Engineer of the Wheeling Steel Corporation, for their interest and encouragement in the preparation of this paper.

COMPRESSED YEAST WASTE TREATMENT *

V. Sludge Formation, Characteristics and Changes

By Willem Rudolfs and Eugene H. Trubnick

Effluents from compressed yeast manufacture (1) contain large amounts of soluble volatile material (7,000 to 15,000 p.p.m.) and have high B.O.D. values (2,000 to 15,000 p.p.m.), but contain relatively low quantities of suspended solids (50 to 200 p.p.m.). In a previous paper (2), it has been shown that the effluents can be effectively treated by anaerobic digestion at B.O.D. loadings 30 to 40 times higher than those used with domestic sewage sludge. On the other hand, the high B.O.D. loadings are not accompanied by similar high suspended solids loadings, as would be the case with domestic sewage, hence the problem of residual sludge produced by yeast waste digestion can be expected to be of less importance. However, to obtain design data for a full scale plant, it was necessary to determine the digested sludge accumulation and its drainability. In addition, studies were made during the course of experimentation concerning the viability of the ripe sludge, its ability to withstand shock treatment, and the amount of seed sludge required for optimum purification.

The digestion was carried out as a continuous process, involving introduction of raw spent nutrient and wash waters at the bottoms of the digestion tanks, passage through a layer of sludge, and removal of the effluent by overflow near the tops of the tanks. This manner of introducing the raw waste was used to achieve maximum contact of the raw material with the seed sludge. To prevent loss of the finely divided ripe sludge from the digesters an intermediate settling tank was provided. The settled sludge was returned daily to the digesters (Figure 1). At very high flows, quantities of sludge escaped even from this tank, and it was necessary to employ additional means of retaining the sludge solids.

The settled digester effluent was treated on trickling filters and the sludge discharged from the filters was returned to the digesters.

Starting the Digesters

The digestion tanks were initially seeded with ripe sludge obtained from a municipal sewage treatment plant. The seed sludge contained large quantities of scum. On account of the upward direction of flow through the digesters, this could not be retained, but overflowed with the effluent to the settling tank. It was necessary to replenish the seed sludge several times. When all the scum had been removed and replaced by additional ripe sludge, the seed consisted of a sludge containing 4.5 per cent total solids, of which 49.5 per cent was ash. The total amount of seed sludge in the digesters amounted to 7,860 lb. dry solids. Spent nutrient and other waste fractions were added in increasing increments and the digestion process was instituted. Operation of the pilot plant was continued for 57 months.

Quantities of Sludge

The amounts of solids added to the digesters over a minimum period of 912 actual working days, expressed in

* Journal Series Paper of the N. J. Agricultural Experiment Station, Rutgers University, The State University of New Jersey, Department of Sanitation, New Brunswick, N. J.

pounds of dry suspended solids, averaged as follows:

Daily addition	190
In digester effluent	1,910
Returned from settling tank	1,720
Returned from settled filter effluent	80
Net addition	80

During this period a series of sludge soundings were made in the digesters in an effort to determine the sludge accumulation. Samples were taken at various levels of the sludge blanket for analysis and calculations of dry solids. The sludge accumulation in the tanks is illustrated by the results recorded in Table I. The usual gradual increase in concentration of solids from top to bottom was present, except during the last sampling, when the tanks had been allowed to rest for a few days in an effort to determine what concentration could be reached with time. Of particular interest is the gradual increase in average solids concentration, during operation, from 4.5 to 7.1 per cent, because of the method of operation. With an upward flow of liquor through the digesters, it might be expected that practically no increase in the density of sludge would occur. The decrease in total solids after one month of operation was due, in part, to further digestion of the seed sludge, as indicated by an increase in the ash content.

TABLE I.—Solids Content in Digesters

Operation Period (months)	Solids in Top to Bottom (%)	Average Solids (%)	Ash in Solids (%)	Total Solids (lb.)	Solids Drawn (lb.)
0	2.7–6.3	4.5	49.5	7,860	—
1	3.9–6.0	5.0	53.5	7,040	—
2	4.9–6.6	5.7	52.2	7,880	—
8	3.2–7.5	6.0	45.0	8,300	900
24	4.8–12.1	7.1	49.0	8,780	900
57	uniform	13.1	50.2	8,820	—

The results show that about 54,850 lb. of dry volatile solids were added to the digesters. About 965 lb. were drawn and about 840 lb. accumulated, on the assumption that all volatile matter in the seed sludge that could be destroyed was decomposed after one month. This assumption appears to be justified when the ash content of the original seed sludge is compared with the ash content of the residue at the end of operation. If further destruction of the volatile matter in the seed sludge took place, it was counterbalanced by a slightly lower rate of destruction of the yeast waste solids. It appears, therefore, that

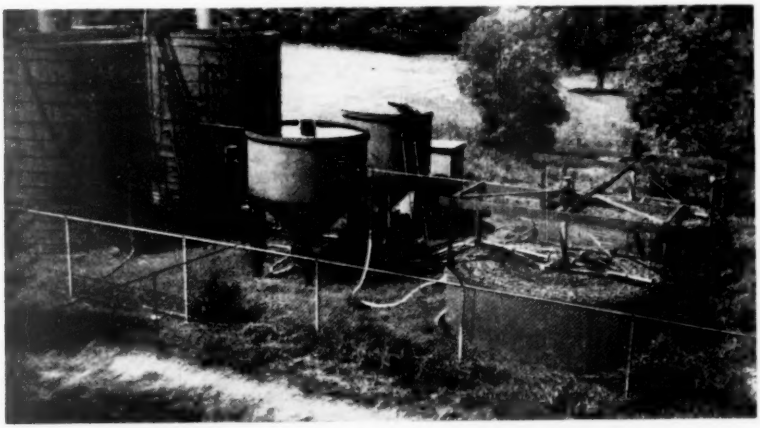


FIGURE 1.—View of digesters, settling tanks, and filters.

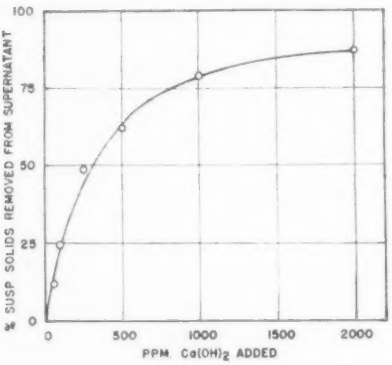


FIGURE 2.—Effect of lime on removal of suspended solids from digester effluent.

about 96 per cent of the volatile matter added as suspended matter was destroyed during digestion. This high percentage of volatile matter destruction is undoubtedly related to the long time of storage of the residue remaining after the first rapid reduction of volatile matter has taken place. Reduction of total volatile solids in the waste, most of which are in soluble form, varied from 60 to 80 per cent with a digestion time of from 1 to 3 days. The volatile suspended solids, comprising only about 1 per cent of the total volatile solids, require a longer time for destruction than does the soluble volatile material. With a storage time of 30 to 40 days a volatile suspended matter reduction of 60 to 70 per cent may be expected; hence, when the residue was left in the tank for many months a very high percentage reduction was accomplished. Under full scale operating conditions the time of storage may not be materially different, because of the relatively slow accumulation of sludge. On the basis of the results obtained over the entire period of experimentation it appears that the average sludge production would amount to about 300 gal. of ripe sludge (7 per cent solids) per million gallons of waste treated, or about 1/5 of the ripe sludge produced from 1 m.g. of an average domestic sewage.

Clarification of Digester Liquor with Lime

During operation of the digesters with varying and increasing volume loadings, it became apparent that hydraulic conditions were such that with certain flows, expansion of the sludge occurred, and with very high flows the sludge could not be retained in the digestion system. Various methods of improving the settling characteristics of the sludge were studied. Preliminary laboratory studies were made with varying amounts of lime slurry added to spent nutrient-sludge mixtures, which represented a 2-day detention period. Typical results are given in Table II, which shows that no material compaction of the sludge took place, but that a highly clarified effluent was produced. The effect of lime on clarification is clearly shown in Fig-

TABLE II.—Effect of Lime on Settling of Spent Nutrient-Sludge Mixtures

$Ca(OH)_2$ (p.p.m.)	Total Column as Supernatant (%)		Susp. Solids in Supernatant After 4 hr. (p.p.m.)	Residual Susp. Solids Removed (%)	pH of Supernatant
	4-hr. Settling	20-hr. Settling			
0	37	50	480	0	6.7
50	40	48	420	12.5	6.7
100	41	51	360	25.0	6.9
250	44	52	280	49.2	6.9
500	36	54	180	62.5	6.9
1,000	12	53	100	79.2	7.0
2,000	29	55	60	87.5	7.2

TABLE III.—Effect of Recirculation on Suspended Solids Content of Digester Effluents (p.p.m.)

Operation Period (weeks)	1st Stage Digester		2nd Stage Digester		Settling	
	Control	Recirculated	Control	Recirculated	Control	Recirculated
1	4,000	1,800	2,400	300	400	600
2	46,200	44,000	2,400	800	800	900
3	36,000	32,400	20,800	1,000	29,600	550
4	11,600	25,400	6,200	16,200	7,000	900

ure 2. Nearly optimum clarification was accomplished with 1,500 p.p.m. lime. On the basis of the laboratory results a quantity of lime equivalent to 1,500 p.p.m. was added to the digesters. The effect of the lime addition was evidenced by the fact that before the addition the suspended solids content of the digester effluents was 20,600 p.p.m. in the effluent from the first stage digester and 19,600 p.p.m. from the secondary digester, whereas two days after the lime had been added the suspended solids contents of the effluents were reduced to 2,000 and 2,600 p.p.m., respectively. Use of lime made it possible to maintain a higher volume loading. Increasing the volume loading again resulted in gradual deterioration of the digester effluent.

Sludge Compaction by Recirculation

With high volume loadings, gas evolution increased. It was considered possible that much of the difficulty in retaining sludge at very high volume loadings was due to entrainment of gas by the sludge particles. In an effort to aid separation of the gas bubbles from the sludge, the digester effluent was recirculated and sprayed over the surface of the digester contents for 10 min. every hour. This treatment was continued for one month. Average weekly results (Table III) indicate that very little, if any, improvement was effected in the first stage digester, with some improvement in the effluent of the second stage digester, and good retention of suspended solids in the settling tank. Recirculation resulted in temporary improvement in the secondary digester, where the sludge was retained for about 3 weeks before excessive suspended solids overflow again occurred. In the settling tank, excessive overflow occurred after 2 weeks without recirculation, but after 4 weeks of recirculation, the suspended solids content of the effluent was still within reasonable limits. In general, recirculation of the digester effluent to prevent excessive quantities of suspended solids passing over the weir of the digester appeared to be of limited value.

Recirculation and Lime Addition

The effect of recirculation in combination with addition of lime was studied by adding 150 p.p.m. $Ca(OH)_2$ to the raw spent nutrient and recirculating the digester effluent for 10 min. every hour. The direction of flow was reversed weekly—that is, the sequence of the primary and secondary digesters was reversed—in order to maintain a balance of solids between the two tanks. The condensed results (Table IV) show that no appreciable improvement resulted in the first stage digester effluent, whereas good retention was obtained in the second stage digester and settling tank. After 4 weeks of operation, excessive amounts of suspended material again began to appear.

From the results obtained with recirculation and lime addition on the retention of sludge for 4-week periods and equal volume loadings, compared with results obtained without treatment (Table V), it is evident that

TABLE IV.—Effect of Lime and Recirculation on Suspended Solids Content of Digester Effluents (p.p.m.)

Weeks Operation*	1st Stage	2nd Stage	Settling Tank
1	20,700	3,000	650
2	32,300	1,200	410
3	35,200	775	225
4	23,000	14,300	630

* 4-day week.

either method of operation is of value for temporary control when sludge expansion takes place. This may be of considerable value in operation when large fluctuations or sudden increases in flow occur, when the strength of the waste is temporarily increased by dumping, when temporary short circuiting occurs, or when the pH value of the waste is unusually low, causing expansion or flotation of the sludge.

Neutralization with Alkalies

The spent nutrient as discharged contains acidic compounds resulting in pH values of 4.0 to 5.0. The effect of neutralizing the acids with alkaline substances, including sodium hydroxide, sodium carbonate, and a highly alkaline waste from a nearby paper mill, in addition to lime, was studied. Sufficient alkali was added to neutralize the raw spent nutrient to pH values of 6.5 to 7.0. In these studies particular attention was paid to the effect of the alkalies on sludge expansion and sludge settling, detention periods varying from 4.8 to 10.5 hr. being used. The sludge particles carried over by the effluent from the digester are finely divided and have a slow settling rate. Results obtained at various detention times and varying concentrations of suspended solids in the effluent of the digester are shown in Table VI. It is evident that for a given detention period higher solids concentrations could be handled, without excessive suspended solids in the settling tank effluents, when the raw spent nutrients were neutralized. Increase in detention time from 4.8 to 6 hr. produced a settling tank effluent with neutralized liquor with a fairly constant suspended solids concentration, whereas without neutralization even 10.5-hr. detention did not produce a settling tank effluent without excessive suspended solids.

TABLE V.—Retention of Sludge in 4-Week Period under Equal Volume Loadings (p.p.m.)

Treatment	1st Stage	2nd Stage	Settling Tank
None (Control)	24,450	17,950	9,450
Recirculation only	25,900	4,575	740
Recirculation plus 150 p.p.m. lime	27,800	4,800	480

Viability of Sludge

Toward the end of the 57-month period of operation, there were some indications that the digestion processes were retarded, particularly evidenced by a lowered efficiency in B.O.D. removal. To determine whether this retardation was the result of deterioration of seed sludge or was caused by other factors, a 2-liter portion of the sludge was transferred to a bottle, spent nutrient was added daily in a manner similar to the procedure of earlier laboratory studies, and a comparison made with freshly acclimatized seed sludge. In addition, a comparison was made with seed sludge that had been used in experimental work for a number of months. The pertinent results obtained were as follows:

	0*	57
Age of sludge (months)		
Spent nutrients (cc./gm. sludge)	2.7	2.9
Gas produced (cc./gm. vol. material added)	120	453
CO_2 in gas (%)	28.1	21.5
Total solids destroyed (%)	51	54
Total vol. matter destroyed (%)	67	77
B.O.D. removed (%)	70	81

* Ripe sludge acclimatized prior to use.

With the loading applied, the results with 57-month-old sludge were similar to the results obtained in the pilot

TABLE VI.—Removal of Suspended Solids from Digester Effluents by Intermediate Settling Tank

Detention Period (hr.)	Digester Influent Not Neutralized (pH 4.0 to 5.0)			Digester Influent Neutralized (pH 6.5 to 7.0)		
	Digester Effluent (p.p.m.)	Settling Tank Effluent (p.p.m.)	Removal (%)	Digester Effluent (p.p.m.)	Settling Tank Effluent (p.p.m.)	Removal (%)
4.8	1,000	550	45	1,100	300	73
	2,400	600	75	33,400	1,050	97
	3,000	600	80	—	—	—
	8,000	950	88	—	—	—
	15,200	2,200	85	—	—	—
	36,000	29,600	17	—	—	—
6.0	1,600	250	85	730	380	48
	23,700	3,960	83	1,400	430	69
	—	—	—	5,300	450	92
7.5	750	250	67	620	250	60
	2,250	325	86	1,100	240	78
	11,800	600	95	1,570	330	79
	27,500	6,750	75	2,300	370	84
	—	—	—	4,000	450	89
	—	—	—	29,700	425	99
10.5	1,800	900	50	1,000	500	50
	7,600	1,600	79	1,400	450	68
	16,000	1,500	91	2,800	500	82
	23,800	7,400	71	3,200	400	88

plant. It is evident that under comparable conditions the old sludge was at least as viable after 57 months of use at it was at the beginning of the pilot plant operation. The retardation observed could not be attributed to seed sludge deterioration. There is a relation between the quantity of seed sludge and the amount of incoming food that can be handled. Within limits, the amount of food that can be assimilated increases with the amount of seed sludge. For optimum results, however, the food must be properly distributed. When the seed sludge concentrates to a high degree, distribution of food becomes more difficult. As indicated in Table I, the sludge concentration increased to more than 13 per cent near the end of the pilot plant run. This concentration interfered with the distribution of the upward flowing liquid, resulting in short circuiting and less contact with the seed material for adequate progress of the biological action. This short circuiting also resulted in an increase of suspended solids in the digester effluent. It appears, therefore, that with the method of operation employed, too much sludge in the digester may be detrimental to best results. Examination of data obtained with various quantities of sludge present indicates that the sludge volume retained in the tank should not exceed half of the digestion capacity.

Operation Under Shock Conditions

To determine the ability of sludge in the digesters to withstand sudden shock loads that might result after the digesters have been out of operation for some time (on account of interruption of production, or maintenance, or repairs), or because of sudden discharge of concentrated liquids as the result of spoilage, an operating schedule of dosing once a week was maintained for 30 weeks. The shock load-

ings varied from 0.250 to 0.335 lb. B.O.D. per cu. ft., or roughly 3 to 4 times the average daily load that normally could be handled without interruption in operation. The average results showed that the reduction in B.O.D. varied from 76.5 per cent for the lower to 71.5 per cent for the higher shock loadings. The removal values coincide with results obtained for similar loadings applied in daily increments. This allowed two important conclusions to be drawn: (1) Shock loads applied for 1 day during normal operation would not materially impair the efficiency of the digesters; and (2) resting of the digesters for a week did not result in deterioration of the seed sludge.

Quantities of Seed Sludge Required

It has been indicated previously that, because of expansion and carry-over of suspended solids, retention of too much seed sludge may be detrimental to purification. It is also obvious that seed sludge in too small amounts would be unable to cope with the maximum amounts of food supplied. Studies were conducted to determine the minimum sludge requirements for optimum purification. In earlier experiments the amount of sludge had been kept constant and daily volume dosages had been varied to determine minimum detention time. In non-agitated mixtures a minimum detention period of 8 days was found necessary for optimum purification (2). This represented daily volume additions of 12.5 per cent to seed sludge with 5 per cent solids concentration, corresponding to 50 gm. dry solids per liter liquid addition daily.

With the previously determined detention period for "proper" loading as well as a reduced detention period or "overloading," the daily volume additions were kept constant but the seed sludge solids in the mixtures were varied in an effort to learn whether the required detention period was determined solely by the amount of sludge present, or whether the sludge quantity was secondary to the total tank volume. Results given in Figure 3 show that with either proper loading or overloading, beyond a minimum required amount of seed, purification in a given time becomes constant as the quantity of sludge increases. The results also show that a minimum of seed sludge is required for good results, and further that by increasing the amounts of sludge in relation to volume loading no optimum purification could be reached. On the other hand, increasing sludge quantities with the same volume loading results in increasing amounts of gas produced. It appears, therefore, that the quantity of liquid addition is related to storage time as well as to the amount of seed sludge, but that a definite minimum amount of seed sludge must be available. The results with overloading show that detention time and B.O.D. loading are more important than increasing the amount of seed sludge beyond a certain minimum. The minimum amount of seed sludge volume (5 per cent solids) required for continuous operation under quiescent

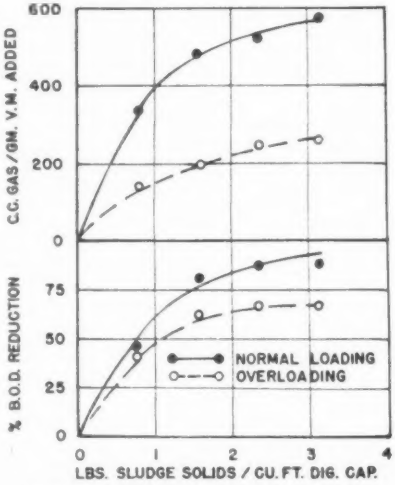


FIGURE 3.—Seed sludge requirement.

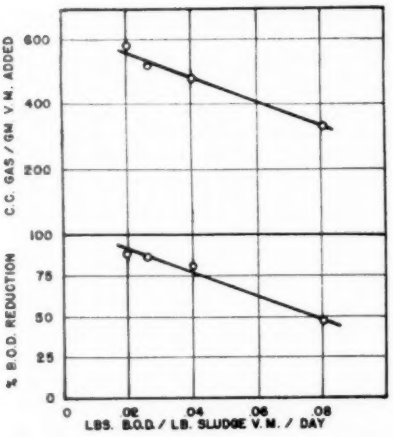


FIGURE 4.—Effect of sludge quantities under normal digester loading conditions.

conditions could not be less than 1/8 of the total tank volume. Hence, proper operating conditions could be maintained if the seed sludge volume was kept between 1/8 and 1/2 of the effective tank capacity.

The relation of loading to sludge quantities is further indicated by Figure 4, in which the percentage of B.O.D. reduction and the gas production are plotted against relatively low B.O.D. loadings, and by Figure 5, in which the same comparison is made for relatively high B.O.D. loadings. It is apparent that increases in load per unit quantity of seed sludge result in lower gas production and lower B.O.D. reduction. The results are for a digestion under quiescent conditions; much higher loadings may be applied with agitation (2).

Sludge Drainability

Although the quantities of digested sludge produced are relatively small, methods for final disposal must be provided. A limited number of experiments were performed to determine the drainability of the digested sludge on sand beds and by vacuum filtration. When digested sludge with a concentration of 6.4 per cent solids was applied at the comparatively low rate of 1⅛ lb. dry solids per sq. ft. (0.86 gal.), the percentage liquid drained was as follows:

Hours	% Liquid Drained
1	31.5
3	43.5
6	48.5
24	52.0

Little water drained during the next 24 hr. The solids concentration after 24 hr. was 17.4 per cent; this is very similar to the drainage of well digested sewage solids. Additional water removal could be accomplished only by evaporation.

Vacuum filtration of the digested sludge with the aid of various amounts of ferric chloride and lime is illustrated by Table VII. The chemicals added

TABLE VII.—Vacuum Filtration of Digested Yeast Waste Sludge

Chemicals* (%)	Filtrate (%)	Vacuum Break (min.)	Solids in Cake (%)	Filtrate Color
0	75	47	22.4	black
5 Fe	57	7	21.4	amber
10 Fe	63	2.5	14.7	light straw
10 CaO	62	100	—	black
20 CaO	55	19	18.7	black
5 Fe plus 10 CaO	53	1.75	18.7	straw

* Fe as $FeCl_3$; CaO as $Ca(OH)_2$.

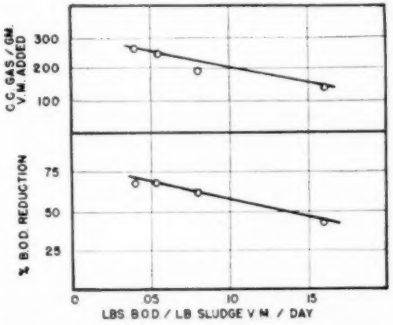


FIGURE 5.—Effect of sludge quantities under conditions of digester overloading.

were on the basis of total dry solids. The original solids concentration of the digested sludge, amounting to 6.85 per cent, was increased to 22.4 per cent by the addition of chemicals, except when 10 per cent of lime was used. The best filtration time was obtained with a combination of 5 per cent iron salt and 10 per cent lime. It appears that the dewatering of the digested sludge by vacuum filtration is difficult and resembles the results obtained with activated sludge.

Discussion

From the standpoint of sludge handling, the anaerobic treatment of effluents from the manufacture of compressed yeast presents a problem different from that of the usual sludge digestion process. The operator of the average sludge digestion plant is mainly plagued with the constant necessity for disposal of digested sludge, rather than sludge retention.

With daily addition of suspended solids amounting to only 1 per cent of the solids in the sludge, and with a high degree of destruction of the suspended solids, it is clear that no rapid accumulation of sludge occurs. Loss of sludge from the digesters, on the other hand, is high because of the finely divided state of the sludge particles, the upward flow involved in the process, and the entrainment of gas on the sludge particles. It is highly important that the flow of sludge solids be kept to a minimum in order that sufficient seed material be retained to carry on the digestion process, and that the material fed to the trickling filters, which comprise the secondary treatment, does not clog the filter media.

By virtue of the presence of additional alkalinity and of mechanical means (spray recirculation), it was found possible to enhance compacting of the sludge and to separate entrained gases from the sludge. The value of such a procedure is primarily for temporary control of operation during periods when sludge expansion takes place, resulting in loss of seed sludge. Buswell (3) reports that continuously operating tanks require reseeding every 2 years, on the assumption that the viability of the sludge gradually decreases. The experiments reported herein show that after 5 years of continuous operation the seed sludge was at least as effective as after one month's operation. The reason for periodic reseeding may be explained by losses of seed, rather than by reduction in biological activity of the sludge. Experimental evidence indicates that too much sludge may be as detrimental to good purification as too little sludge. It is essential to maintain optimum volumes of sludge by judicious sludge withdrawal, but to prevent too much accumulation. At the same time, it is essential to maintain effective control of the digester effluent over a peripheral weir, together with proper distribution of the raw liquor through the seed sludge. The method of introducing raw waste into the bottom of the digester through slowly rotating perforated pipes appears feasible and practicable.

Inasmuch as the amount of volatile suspended solids comprises only about 1 per cent of the total volatile solids in the raw waste and retention of the sludge in the tank is long, it can be expected that only comparatively small amounts of sludge remain for final disposal. The quantities of sludge produced during the extended period of operation appear to be of the same order as those obtained with similar wastes by Jensen (4), who pointed out that it was necessary to draw sludge only after 4 years of operation. Our results indicate that frequent drawing of small quantities of sludge is preferable to retention of sludge in the digesters for long periods.

The manufacture of yeast is essentially a batch process. Therefore, long week-end rest periods may be encountered. Interrupted operation, together

with the possibility that batches may be dumped, may place a heavy load on the digesters. The ability of anaerobic processes to withstand sudden wide variations in load, provided sufficient ripe sludge is available, is well known. The experiments have shown that the same holds true for treatment of yeast effluents.

The digested sludge can be dewatered on sand filters and, with the aid of chemicals, on vacuum filters. The loadings would be less, however, than with digested sewage sludge. The behavior of the digested sludge in vacuum filtration is similar to that of activated sludge, probably because of the extremely fine particles with relatively large surfaces which retain the water.

It is frequently assumed that soluble volatile matter should digest at a higher rate than suspended volatile matter, because the suspended complex material must be liquefied before further decomposition can take place. If this assumption is correct, one would expect to find that the loadings, expressed either as volatile matter or as B.O.D. per unit of seed material or per unit of digestion capacity, would be greater with soluble material than with suspended solids, provided such environmental conditions as temperature and reaction are the same. It is of particular interest, therefore, to compare volatile matter and B.O.D. loadings of material such as yeast waste, which is mostly soluble and colloidal in nature, with domestic sewage sludge consisting preponderantly of suspended organic matter.

Under quiescent conditions at 82° F. digestion temperature, the B.O.D. loading of yeast waste was found to be equivalent to 0.02 lb. B.O.D. per lb. of volatile matter in the seed sludge, or a daily addition of 3 lb. of volatile matter per 100 lb. of volatile matter in the seed. The relation between B.O.D. and volatile matter in the raw waste is 1:2.5. This is of the same order as the B.O.D.-volatile matter ratio in fresh sewage sludge. The volatile matter loadings in sewage sludge digesters kept at 82° F. is about 5 per cent per day, or an equivalent of 0.02 lb. B.O.D. per lb. of volatile matter. It appears, therefore, that soluble organic matter is not decomposed at a greater rate than suspended organic material, when a specific percentage B.O.D. reduction, volatile matter reduction, or gas production is to be accomplished under quiescent conditions.

However, when an intimate contact of the yeast waste with the seed sludge is maintained (stirring), an 80 per cent B.O.D. reduction is obtained with an addition of 20 per cent volatile matter. This means a loading of 0.2 lb. volatile matter per lb. of volatile matter in the seed sludge, which in turn is equivalent to 0.08 lb. B.O.D. per lb. of volatile matter, or a loading four times as great as under "quiescent" conditions. Various methods employed to mix fresh solids with seed sludge also allow higher loadings.

It would seem that development of proper methods of mixing fresh sewage solids with seed sludge, either in one tank or in a series of tanks (in so-called "stage" digestion tanks), may lead to material reduction in required digestion capacities, or to increased loadings.

Summary

Studies on the quantities of sludge required for efficient operation of digesters for compressed yeast wastes, on the volumes of sludge produced, and on its characteristics, show that definite minimum quantities of seed sludge are required, but that excessive quantities are detrimental to good purification. Because the suspended solids present are only 1 per cent of the total solids in the waste, sludge accumulation is slow. Neutralization of the raw spent nutrient to about pH

6.5, with concomitant increase in alkalinity, results in greater retention of sludge in the digesters and improves sedimentation of sludge in a subsequent settling tank, preventing sludge losses. Spray recirculation of the digester effluent enhances settling of sludge by virtue of the separation of entrained gas. Seed sludge originally procured from a municipal sewage plant remained viable for at least 5 yr. and no reseeding was required. The sludge is capable of withstanding shock loads with no apparent retardation of the purification processes. Drainability of the digested sludge is poorer than that of digested sewage sludge, and vacuum filtration with chemicals produces results similar to that obtained with activated sludge. Proper mixing of raw waste with the seed sludge allows higher loadings than does digestion under "quiescent" conditions.

References

1. Rudolfs, W., and Trubnick, E. H., "Compressed Yeast Waste Treatment. I." THIS JOURNAL, **20**, 6, 1084 (Nov., 1948).
2. Rudolfs, W., and Trubnick, E. H., "Compressed Yeast Waste Treatment. II." THIS JOURNAL, **21**, 1, 100 (Jan., 1949).
3. Buswell, A. M., "Important Considerations in Sludge Digestion. II." THIS JOURNAL, **19**, 1, 28 (Jan., 1947).
4. Jensen, R. E., "Purification of Waste Water from Yeast Factories." Trans. Chem. Eng. Congress of the World Power Conf., III, 253 (1937).

OHIO VALLEY PHENOL WASTES REDUCED

Eighty per cent of the phenol waste from by-product coke plants, heretofore discharged into the Ohio River and its tributaries, has now been eliminated according to the Ohio River Valley Water Sanitation Commission. The Commission reached its conclusion from an analysis of corrective measures taken by the major coke-producing plants in the Ohio River basin. These plants have placed in operation facilities for minimizing the objectionable effects of wash-water wastes, either by installation of closed circulation systems or by recovery of phenol as a usable by-product.

The Commission's investigation included all 23 by-product coke plants within the basin. Depending on location, these facilities remove from 80 to 99.5 per cent of the phenolic compounds that otherwise would be discharged directly into the streams. At 10 plants, where treatment measures are not adequate, notification has been given or plans are being made to improve the situation. The report on phenol-pollution control was made by a committee of the Commission consisting of the following state sanitary engineers: F. H. Waring, Ohio (Chairman); F. C. Dugan, Kentucky; K. S. Watson, West Virginia; and H. E. Moses, Pennsylvania.

Stream Pollution

LEGAL INDICES OF STREAM POLLUTION *

By Don E. Bloodgood

Professor of Sanitary Engineering, Purdue University, West Lafayette, Ind.

The rendering of justice is one of the most difficult maneuvers undertaken by man. The primary reason for this difficulty is that the differentiation between things that are right and wrong is based on belief in conformity to spiritual law or on the following of traditional standards. Common law, the unwritten law that receives its binding force from immemorial usage and universal reception, together with statute law are generally believed to be a reasonable attempt by man to determine right from wrong in a fair way.

Those who are familiar with law and courts know, however, that there often have been cases with almost similar evidence presented, but with opposite findings by the courts. It is not uncommon for a higher court to reverse the decision of the lower court. There are even instances where the same court has heard the same case several times with several reversals of opinion (1). Such inconsistencies leave one wondering whether or not there are truths definitely established in the courts. Certainly, however, when matters are brought into court there is reason to believe that the plaintiff feels that there has been an injustice done but the injustice may or may not be sufficient in the opinion of the court to award damages. Nevertheless, the decision of the courts is very helpful in establishing basic information that will indicate to possible offenders the degree of stream pollution that is likely to be brought before the courts. Phelps and Montgomery in 1917 reviewed and reported on some 350 court cases where the plaintiffs were claiming pollution of streams and other bodies of water. The abstracts of these cases were made with the view of bringing out whether the defendants in the cases had inflicted damage recognized as such under either common law or statute law. The attitudes of the courts have been such that nearly all attention has been given to the effects upon the plaintiffs, their rights, or properties, with but little attention given to the actual condition of the receiving stream. Howland and Wiley (2) in their discussion on "How Do You Determine When a Stream is Polluted" stressed particularly the minimum standards that have been established under authorization by state laws. They also stressed the importance of the attitude of reasonableness on the part of regulatory agencies in carrying out their enforcement programs.

At present, neither the court decisions indicating damage, nor the minimum standards for streams established by regulatory agencies, suffice to answer the question asked by many industries: "What degree of treatment must be provided for our particular waste?" Hart (3) says, ". . . industry is wondering how it is to know when and under what conditions it will know that the program (their waste treatment program) is satisfactory. . . . Surely this cannot be answered in terms or degree of waste treatment alone. . . . Examination of

* Presented at Twenty-first Annual Meeting, Federation of Sewage Works Associations; Detroit, Mich.; October 18–21, 1948.

the stream itself will show when the job is done." He then goes on to say that the chemical and biological examinations of streams will indicate whether a satisfactory job is being done. The question will then arise as to who will pass judgment on when a stream is or is not in a satisfactory condition. True, laws and regulations must be obeyed if and provided, of course, they meet that requirement which states in substance that statute law must be reasonable. The reasonableness of law or regulation is affirmed by court action. Court cases that will establish suitable chemical and biological conditions of streams have apparently not been before many of the courts, and as a result such information is not yet available; at least it is not readily available. Until such time as the minimum requirements of law and regulation are being considered in court it is necessary to refer for basic reference to those court cases where the degree of pollution was in some way established by the evidence presented.

In the case of the Paragon Paper Co. *v.* The State (Indiana) in the Apellate Court of Indiana (4) the evidence from the lower court read as follows:

". . . that appellant (Paragon Paper Co.) unlawfully and injuriously caused, suffered, and permitted, and still does cause, suffer, and permit, offal, filth, and noisome substances and fluids to be collected and deposited, and remain in said river, and cause the same to flow into said river, and along and down said river, in and with the water thereof, and to settle and be deposited and remain upon the banks and bed of said river, forming a noxious, noisome, and offensive slime adjacent to said factory, and downward therefrom, along the course of said river, a distance of eight miles, whereby the water in said river then and there was polluted, and rendered noxious, impure, poisonous, offensive, discolored, stinking, and unwholesome for man and beast and whereby the atmosphere for a distance of two miles on each side of said river, and for a distance of eight miles along the course of said river. . . ."

Even though the upper court reversed the decision of the lower court no mention is made that it did so on the basis that the evidence presented did not prove that the river was polluted by wastes from a paper company.

From this cited experience it can be concluded that any discharge into a stream that will deposit objectionable solids and slimes upon a river's bottom or banks may bring about court action. It is such evidence as given that backs the regulation of the Ohio River Valley Compact; that is, "All sewage . . . shall be treated . . . to provide for substantially complete removal of settleable solids, and the removal of not less than forty-five per cent (45%) of the total suspended solids."

The next case cited is also one involving paper companies. There is no intention of particularly pointing out this industry as a perpetual offender, but because of the meager evidence in these court cases that can be used it is necessary to resort to available information.

The West Muncie Strawboard Co. appealed its case to the Indiana Supreme Court (5) after the plaintiff, Slack, had won his case in the Circuit Court. The evidence submitted included the following:

"White River, which stream is a natural watercourse; that prior to the commission of the acts complained of (erection and operation of paper factories), this stream was well adapted to the watering of cattle and to other agricultural purposes, and was well stocked with fish: . . . that each of the appellants in the operation of its respective mill, discharged large quantities of chemicals and other deleterious substances into the waters of Brick Creek and White River, thereby destroying the fish in said streams, creating noxious vapors, and breeding large numbers of flies and other insects; . . ."

The Supreme Court "finding no error the judgment is affirmed."

Wastes containing chemicals that will kill fish are, according to the court finding, objectionable in a stream. In this case, as in the one previously cited (4), noxious odors from the receiving stream were one of the objections of the plaintiff that was taken into consideration by the court. It might also be concluded that the discharge of a waste that provided food and a breeding place for insects is objectionable and in the eyes of the court a reason for insisting on corrective measures.

In the case of Luther *et al. v.* Village of Batavia (N. Y.) (6) damages were awarded against the city for pollution of a stream by municipal sewage, because ". . . the evidence fairly shows, . . . that the waters of this stream became contaminated with offensive matter from sewers; that the waters of the stream were covered with a scum, gave off at times offensive odor, became so filthy that the cattle would not drink of it, and that fish died; and that the filthy odor of the creek caused discomfort and annoyance to the plaintiff. . . ." It is realized that it may have been the combination of all of these complaints that influenced the court in its decision, but it seems reasonable to believe that each complaint in itself would be objectionable.

Special attention is called here to the statement that scum on the water surface is objectionable and may in other cases be reason for complaint and court action.

Henry Kraver, a distiller of Henderson, Ky., was not satisfied with the decision of the lower court when he and the City of Henderson were sued for damages for polluting Canoe Creek. Therefore, he took his case to the Kentucky Court of Appeals where, on a technicality, the findings of the lower court were reversed. The higher court did not refute the evidence, which showed that:

"For several years last past until Aug. 1912 the appellant (Henry Kraver) has had a private sewer extending from the distillery into the creek, which carried off during the times of the operation of the distillery very large quantities of slop arising from the distillation of corn and other grain. This slop when it first leaves the distillery is milky white in color and flows easily, but when it reaches the creek it settles to the bottom, and by exposure to the action of the water and air after a time the solid elements in it turn very black, decompose, and give off a very nauseating odor. On account of the current being sluggish, the solid elements of this slop settle and form a substance upon the bottom of the stream, which continues, in fact, for months thereafter. . . ."

It is believed that this evidence indicates that a discharge of any waste such as distillery slop to a stream in a quantity sufficient to cause deposition of solid material on a stream bottom with eventual decomposition would in all likelihood be considered a troublesome pollutant.

In the Mayor of Baltimore *v.* Warren Manufacturing Co. case (7) the evidence stated:

"What nature and extent of pollution of the stream will call for the active interference of the court is not in all cases easy to defend. It is not every impurity imparted to the water, however small in degree, that will be the subject of an injunction. All running streams are, to a certain extent, polluted; and especially are they so when they flow through populous regions of country and the waters are utilized for mechanical and manufacturing purposes."

It would seem that perhaps the court was impressed that the amount of polluting material to which the plaintiff was objecting was very small, but it must be remembered that this case was heard in 1882. What might have been called minor pollution then might today be considered gross pollution. The point to be made in this case is that even minor pollution may be brought to the attention of the court.

In the case of Worthen & Aldrich *v.* the White Spring Paper Co. (8) the

defendant was engaged in the manufacture of paper from pure cotton and linen rags in a mill about ¼ mile above the works of the complainants. The evidence states that:

"the pollution consisted of placing in the stream large quantities of waste cotton fiber, the particles of which varied in length from 1/32 to 3/8 in. and at times the deposit was in such quantities as to be actually visible to the eye in the discoloration of the water of the canal and river and in the deposit of quantities of the same material on the ground forming the banks and beds of these waterways."

This case points out the possible objection that may be raised to the discharge of organic fibers into a stream. In this particular case the fibers were clogging screens used by the plaintiff.

Quoting from MacNamara v. Taft (9):

"the evidence shows that the defendant used daily at this mill (for manufacture of satinet cloth) a large quantity of oil, put upon the material before it is spun, and 180 pounds of soap, 165 pounds of soda ash, 45 pounds of soda salts, 200 pounds of extract of logwood, and 43 pounds of blue vitriol in fulling and dyeing his cloth. After these chemicals are put into the fulling mill and taken up by the cloth, the cloth is placed in washers and washed. A large part of the logwood and vitriol, and substantially all of the other chemicals, are washed out and discharged into the stream. The effect of this discharge is to make the water dark in color and to give it an oily odor and taste such as to prevent the plaintiff's cows from drinking it. . . ."

The stream that received these materials was, in its natural state, 8 to 12 ft. wide and from 3 to 6 ft. deep. The logwood probably was responsible for some or all of the color to which objections were made. The oil and perhaps some of the grease from the soap would float, and the court apparently objected to this characteristic of the waste. Perhaps no attempt should be made to indicate the possible objections to the individual constituents of the waste, but rather make a general statement saying that a combination of noticeable quantities of the several compounds will be objected to by regulatory agencies or riparian owners below the point of discharge of the waste into the stream.

In the case of the Silver Spring Bleaching and Dyeing Co. *v.* The Wanskuck Co. (10) an injunction was granted against the defendant, a woolen goods manufacturer, who was polluting a stream by means of dyestuff to the injury of the plaintiff, a cotton goods manufacturer. It is indicated in this case that it was only the discoloring of the stream that brought about the court action.

A peculiar decision was handed down in the Hill *v.* Standard Mining Co. case (11), where the plaintiff was sueing for damages resulting from discharging debris and poisonous substances (lead, arsenic, etc.) into the stream. In this case the court ruled that the defendant had no right to change the course of the stream by dumping debris into it, but the dumping of the poisonous substances was ruled as a necessary process in the mining operation. This particular illustration is cited to show the peculiarities of court decisions, and at the same time to show that the discharge of poisonous substances such as arsenic and lead can be considered as a logical reason for bringing court action against an offender.

In the much quoted Sanderson case (12) the plaintiff alleged in her complaint that "the large volume of mine water, which the defendant company poured into the brook above, had corrupted the stream to such an extent as to render it totally unfit for domestic use; that the fish were destroyed, the pipes corroded, and the entire apparatus for utilizing the water was rendered worthless." This case was twice decided in the plaintiff's favor in the Supreme Court of Pennsylvania, but

it was brought before the court a third time, and four judges out of seven held that the plaintiff was entitled neither to damages nor to an injunction. From such a record it is safe to say that a similar situation of mine waste discharge would today receive attention, and that the discharge of any waste doing similar damage would be considered a pollutant. The company discharging any such waste could certainly expect court action to be taken if it did not proceed to correct the trouble at once.

In Kinnaird *v.* Standard Oil Co. (13) the defendant had stored petroleum, which leaked and percolated through the ground until it reached the plaintiff's spring of water. The pollution of waters with even small quantities of oil results in demands for justice from the courts. It is entirely possible that contamination with other substances may result if objectionable materials are stored in quantities in earthen lagoons, or the discharge of waste waters into underground strata is permitted.

In Berry *v.* Shell Petroleum Company (14) Berry claimed that salt water had seeped from the municipal sewer system into the ground water and had finally damaged the water supply on his property. This is not a direct case of stream pollution, but it serves as a possible indication to those who may consider or wish to discharge salt brine wastes to receiving waters. No mention is made in the information available on this case as to whether the brine materially changed the taste of the water supply, or whether it changed the chemical characteristics, such as the hardness.

At present there is some discussion among states in the Ohio River Valley regarding the discharge of brine into the Ohio River to the extent that it would slightly increase the hardness of the river water. The Berry case may be of help in settling the Ohio River brine waste problem.

In the Masonite Corporation *v.* Hill (15) case, Hill had originally filed suit for damages resulting from bathing in poisonous water in a running stream contaminated by wastes from the Masonite Corporation mill. The manufacturer testified that the only chemicals discharged into the stream were caustic soda, petroleum, and methyl alcohol. The court believed that Hill should have proved that poisonous substances were present in the water by having a chemical analysis made of the water.

Here again, technicalities may have influenced the findings of the court. It is indicated that should discharges of caustic, petroleum, or methyl alcohol be such as to cause skin irritation the producers of the waste would be faced with court action. March (16) says that it takes only 18 p.p.m. of caustic lime in water to kill fish. It has not been possible to establish this concentration from evidence presented in the courts.

This collection of information from court cases is only a very small fraction of that needed to establish a basis for indices of stream pollution. State laws governing pollution of streams in the several states are, in general, no more rigid than the precedents set up in the court cases cited. The Illinois act, establishing a sanitary water board to control, prevent, and abate pollution of streams, lakes, ponds, and other surface and underground waters in the state, is a good illustration of a reasonable and effective law.

If the court actions cited are compared to the Illinois act, it will soon be apparent that in general the court evidence gives backing to the law. This certainly should add strength to all similar pollution laws because it establishes their reasonableness with court decisions.

The accumulation of more court evidence showing the condition of streams is recommended. It is believed that a complete compilation of all available

court evidence that shows the condition of streams declared by the court to be polluted would be of material help to all who are interested in pollution abatement.

Acknowledgment is made of the assistance given in collecting the data used herein by R. A. Canham, Sanitary Engineer, National Canners Association, Washington, D. C., and W. E. Dunn, Sanitary Engineer, Florida State Board of Health.

References

1. Montgomery, S. D., and Phelps, E. B., "Stream Pollution." *Public Health Bulletin No. 87*, p. 31 (Nov., 1917).
2. Howland, W. E., and Wiley, R. B., "How Do You Determine When a Stream is Polluted?" *Proceedings of the Third Industrial Waste Conference*, Purdue University Extension Bulletin Series No. 64, p. 16 (1947).
3. Hart, W. B., "Waste Treatment Problems from the Viewpoint of Industry." THIS JOURNAL, **20**, 2, 273 (Mar., 1948).
4. Appellate Court Records of Indiana, November Term, 1897, Vol. 19, p. 315.
5. Supreme Court Records of Indiana, November Term, 1904, Vol. 164.
6. Luther *et al. v.* Village of Batavia (154 N. Y. Supp. 784) (July 7, 1915); and U. S. Public Health Reports, **31**, Part 1, p. 29 (1916).
7. Mayor of Baltimore *v.* Warren Manufacturing Co. (59 Md. 96); also Ref. 1, p. 10.
8. Worthen & Aldrich *v.* White Springs Paper Co. (74 N. J. Eq. 647); also Ref. 1, p. 21.
9. MacNamara *v.* Taft (196 Mass. 597; 83 N. E. 310; 13 L.R.A. (N.S.) 1044); also Ref. 1, p. 19.
10. Silver Springs Bleaching and Dyeing Co. *v.* The Wanskuck Co. (13 R. I. 611); also Ref. 1, p. 23.
11. Hill *v.* Standard Mining Co. (12 Idaho 223); also see Ref. 1, p. 25.
12. Pennsylvania Coal Co. *v.* Sanderson (113 Pa. St. 126; 57 Am. Reps. 445); also see Ref. 1, p. 31.
13. Kinnaird *v.* Standard Oil Co. (89 Ky. 468).
14. Berry *v.* Shell Petroleum Co. (140 Kan. 94); also Parker, Leo T., "Pollution Law Suits." *Sewage Works Engineering*, **19**, 3, 138 (Mar., 1948).
15. Masonite Corporation *v.* Hill (154 So. 295); also Parker, Leo T., "Pollution Law Suits." *Sewage Works Engineering*, **19**, 3, 138 (Mar., 1948).
16. March, M. C., "The Effect of Some Industrial Wastes on Fishes." U. S. Geological Survey Water Supply and Irrigation Paper, 192 (1907).

INDICES OF STREAM POLLUTION—A DISCUSSION

By Robert N. Clark

Chief, Public Health Engineer, Tennessee Valley Authority, Chattanooga, Tenn.

Professor Bloodgood's approach to the Indices of Stream Pollution is extremely gratifying. Instead of a learned and highly technical discussion of the limits, possibly to the last decimal place, that should be placed on B.O.D., dissolved oxygen, coliform organisms, solids, and a host of other constituents, he has taken us right back to the fundamental fact, which is liable to be forgotten or ignored, that laymen provide the necessary funds and will constitute the jury that passes final judgment on the success or failure of all stream sanitation programs. Any stream sanitation program which ultimately does not satisfy the public and give it what it wants is doomed to failure.

This is not to imply that all of the tediously fashioned technical tools for measuring and evaluating the effects of stream pollution, and for calculating the reduction in pollution necessary to restore acceptable water quality in the stream, should be discarded immediately. Those things that are known to be necessary to restore a sick stream to health must be continued, but the noticeable symptoms

that accompany the sickness must also be removed.

As long as those symptoms remain, the layman finds it extremely difficult if not impossible to understand that anything actually has been accomplished. Neither being equipped with nor understanding the use of all the intricate paraphernalia of the laboratory, he logically uses for measurement those tools with which he is naturally endowed—his senses of feel, sight, smell, and taste—in his judgment of a stream. If his drinking water, taken from a river and passed through a treatment plant, tastes, smells, or looks bad, or makes him sick, either the river is polluted, or the water plant operator put too much chlorine in the water. If unnatural odors arise from a stream, or the stream bed is clogged with deposits, or the surface is covered with unnatural floating matter, including dead fish, or the water is highly or unnaturally colored, or its clarity is reduced by suspended matter, it is polluted. It is as simple as that. Great difficulty will be encountered in convincing him otherwise, despite the overwhelming evidence of the most refined bacteriological, chemical, and biological measurements.

There is a definite need for better understanding between the sanitary engineer dealing with stream pollution and the public. Engineers are prone to feel just a bit superior and to insist that they know what is best for the public because they understand, at least partially, the mysteries of the natural phenomena through which a stream purges itself of pollution. It has been found that many of these phenomena can be formulated and defined in numerical terms. Scientists, by basic training and perhaps by inherited inner compulsion, shy away from those things that cannot be tied up in neat mathematical packages. We feel helpless, however, when faced with the necessity of evaluating such intangibles as human psychology, which cannot be expressed in numbers with the decimals all properly in place. Nevertheless, the psychology of man's basic reactions to water, which in ancient times was listed as one of the four elements of which the universe was composed, is a factor that must not be omitted in any formula set up to calculate what corrective measures a polluted stream requires.

It is difficult even to put in words, much less to put in a formula, but there is a human instinct that reacts spontaneously to the feel and sight of clear, clean water. It is so deeply ingrained and so difficult to rationalize that it must have deep roots in primitive man's complete dependence on springs and streams for his very existence. Relaxation of our scientific prejudices, and purely emotional contemplation of some of our own reactions to water, may help to place this proposition in its proper perspective.

Childhood memories that remain longest are the pleasures of fishing in a quiet pool and frolicking in the old swimming hole. Nothing can arouse a greater sense of injustice and rage than to return after many years and find these waters despoiled by pollution. The real fisherman's fascination with fishing cannot be attributed entirely to the fish he catches, for he returns home empty handed time after time, yet always goes back again. The pressure and relaxation derived from close association with water must account, at least in part, for his devotion to the sport. On a picnic one seeks, without conscious volition, a spot near clear running water or a quiet lake. Even the soggy bun and the cold hot dog taste much better when there is the sound of running water in the background or the sight of calm water in the foreground. A beautiful scene relaxes inner tensions and soothes the soul. It is all the more effective if a

blue lake is a prominent part of the landscape or a majestic river occupies the foreground. Can there be any denial that these simple pleasures are essential in our scheme of things?

However, the noticeable effects of pollution—objectionable floating materials, turbidity, color, taste, and odor; those things to which the layman objects—not only deny the relaxation these essential pleasures would bring, but actually add to the tensions that are inevitably a penalty of modern civilization through the irritations aroused by despoilation of an important feature of mother nature's beauty.

This may sound like a plea for pristine purity of streams. It is not intended as such. It is a rebuttal, rather, to those who claim that a pollution control program must be based on an exact dollars and cents balance of cost of corrective measures against value of benefits derived. This philosophy may be the natural result of the scientist's essential faith in figures, but the side of the scale in favor of correction all too frequently will be short weighted unless the dollars and cents values of the aesthetic pleasures can be included. Who can assess these values? Certainly neither any single individual, nor any limited group of individuals. Those who have faith in the democratic process believe that the opinion of the majority, although it may vacillate, eventually arrives at a sound conclusion. Technical man must take care of the technical indices of pollution, but the public opinion of stream sanitation is going to be based on those things that the public can feel, see, taste, and smell. It must not be forgotten that in the end success in stream sanitation will be judged by a jury of laymen.

ACTION URGED BY POLLUTION CONTROL BOARD

As part of a far-reaching program to improve and safeguard the nation's water resources, the new Water Pollution Control Advisory Board (THIS JOURNAL, **21**, 2, 552; May, 1949) decided at its organization meeting in May to hold a number of future meetings in different parts of the country and obtain first-hand information on the water problems of specific areas.

Although the Water Pollution Control Act passed by Congress in June, 1948, authorizes Federal expenditures for loans and other assistance over a 5-year period, no specific appropriations have yet been made. Bills now before Congress do not provide for construction loans. However, it is believed by the Board that ample financing through non-Federal channels is available for considerable pollution abatement work. Accordingly, the Board urged municipalities which might be delaying construction of sewage treatment works in the hope of Federal financing to proceed with their projects at the earliest possible time.

It also recommended that the Government push ahead with the planning of a comprehensive program and continue to offer such technical guidance and assistance as possible under the Act, in preparation for fuller development of the program in the fiscal year 1951.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

THE LIFE YOU SAVE . . .

A valuable lesson can be learned from the experience of John Hood, Superintendent at Ridgewood, N. J., as related in an article in The Corner this issue. The reported rupture of a chlorine cylinder, presumably by internal damage due to moisture previously introduced by back-siphonage, is typical of the manner in which catastrophe can strike. It happened before; it can happen again. Even now, a cylinder with incipient failure of this type may be standing on the scale or in the storage rack of one or more sewage treatment plants. Who can know the internal condition of the cylinders delivered to him?

Obviously, chlorine demands a healthy respect. Equally obvious is the necessity of being prepared to cope with its leakage, not only in the small quantities of joint leaks, but also in the wholesale quantities involved in the failure under discussion. The special equipment needed must be on hand and in top flight condition; personnel trained in its use must be always immediately available. Several good publications covering these subjects are procurable, notably the Federation's "Safety Manual" and the manuals of the major chlorine manufacturers.

Emergency procedures should be worked out beforehand and then made a part of the finger-tip knowledge of all plant personnel. Major points to cover include:

1. Summoning aid, not only to the plant, but also for evacuating residents of areas that might be affected.

2. Disposing of the leaky container by immersion in a flowing or large body of water, by burial in moist earth, or by caustic soda neutralization.

3. Ventilating and decontaminating, as far as possible, equipment and enclosed areas involved.

If, despite all precautions, someone is poisoned by the gas, loss of life or permanent injury may be prevented by the observance of these few simple rules:

1. Remain calm, promptly remove the patient to the open air away from any traces of chlorine, place him on his back with head slightly elevated, and keep him warm.

2. Call a physician immediately.

3. Remove any clothing contaminated by liquid chlorine or chlorinated water.

4. If the patient is unconscious and not breathing, administer artificial respiration.

5. Provide first aid pending the physician's arrival. In this connection, relief from coughing and gagging can be effectively provided by having the patient inhale steam from very hot water to which a few drops of tincture of benzoin has been added.

Don't wait for something to happen. Check now and periodically on your emergency equipment and the training of your personnel. In dealing with chlorine two slogans may well be kept in mind—"Be Prepared," and "The Life You Save May Be Your Own."

H. P. O.

CHLORINE CYLINDER RUPTURE AT RIDGEWOOD SEWAGE TREATMENT PLANT

By John W. Hood

Superintendent, Sewage Treatment Plant, Ridgewood, N. J.

About 7:00 P.M. on June 15, 1948, the operator on duty at the Ridgewood, N. J., sewage treatment plant noticed what appeared to be smoke coming from one of the frame buildings several hundred feet distant from where he was at work on the grounds. Thinking that fire had broken out, he immediately ran toward the building to find out what the situation was. On nearing the building he ran into the "smoke," only to discover that it was in reality escaping chlorine gas. He made a hasty retreat and telephoned for assistance.

When the writer arrived a few minutes later, he found that the poisonous fumes were already enveloping other nearby buildings and units; he was able to make only one telephone call, to the fire department, before being driven out of the plant grounds altogether. Atmospheric conditions were heavy and wet, with intermittent rain and variable light air movement. The police departments of Ridgewood and Glen Rock were telephoned from a nearby residence. In the course of the ensuing 5 hours it was necessary to evacuate residents of adjacent residential sections as the varying ground currents of air carried the billowing clouds of chlorine gas first this way, and then that, but thanks to the timely assistance of the two police departments, equipped with 2-way radio communication, no persons sustained injury and only a few complained of minor irritation. By midnight, all persons evacuated had been restored to their homes. Medical attention was required for the operator and a passerby, both of whom inhaled the "smoke" before realizing their danger. Neither sustained permanent injury.

Fire department personnel, equipped with facial masks and cylinders of compressed air strapped on their shoulders, entered the chlorine room, disconnected the ruptured cylinder, and immersed it in a nearby flume. Assistant Chief Haldane later advised that neither he nor any other participating member of the department had suffered any ill effects and did not require medical care—a good recommendation for the type of equipment used, in view of the high concentration of chlorine gas and possible near or total depletion of oxygen in the room where the cylinder had ruptured.

Figure 1 shows the cylinder whose wall ruptured near the foot ring. Two cylinders, each containing 150 lb. of chlorine, were mounted on the platform scale and connected to a chlorinator of the vacuum feed type. The

FIGURE 1.—Rupture resulting from internal erosion due to moisture in chlorine cylinder.

chlorine machine was not in use at the time of the accident and both the auxiliary valves and the main cylinder valves were closed. Brown liquid emitted from the ruptured cylinder was found on the adjacent wall and surrounding floor. It had no apparent chlorine odor and was concluded to be ferric chloride, resulting from internal erosion of the steel tank wall, indicating that moisture had been present in the tank at or before the failure of the tank wall. The defective cylinder was retained at the sewage plant as evidence, pending any possible legal developments. It was eventually released to the vendor for further joint examinations by themselves and the Chlorine Institute, the latter being represented by H. A. Faber, Research Chemist.

The vendor was summoned to the plant to observe conditions attending the cylinder rupture. He was requested to make immediate arrangements for the removal, without prejudice, of the remaining stock on hand, consisting of 8 full cylinders, or a net total of 1,200 lb. chlorine, from the sewage plant. This was done the following day.

During the subsequent discussions on the matter the author contended that admission of water to cylinders was highly improbable where vacuum chlorinators, such as employed at Ridgewood exclusively, were used to discharge the contents, but that it had been known to occur in bleach plants where this type equipment is not generally in use. Mr. Faber's report on the itinerary of the ruptured cylinder discloses that it had been to a bleach plant a short time before coming to Ridgewood.

The concern expressed by Ridgewood officials over the problems posed by this incident have been countered with statistics purporting to show that because of the over-all picture and the low incidence of accidents of this type, there is nothing to be unduly concerned about.

However, those in responsible charge have different ideas on that point and are honestly striving to profit individually and collectively by the unfortunate experience. No serious personal or property damage resulted, due to a number of contributing factors, but we might not be so fortunate next time.

In conclusion, the author would like to point up a few timely thoughts for plant superintendents to ponder:

1. For oxygen deficient conditions, it is unsafe to rely on mask equipment unless it features a portable and independent supply of air.

2. Such equipment necessarily must be housed in an independent and comparatively remote building, where it will be accessible in an emergency.

3. In close proximity to dwellings, the stock of chlorine on hand should be kept at a minimum, and special provisions (preferably automatic where 24-hr. attendance is not afforded) should be made for neutralization of escaping chlorine. It is generally admitted by sewage and water men contacted since this cylinder failure that they have no way at all of dealing with possible rupture, particularly of ton containers, and merely accept the cylinders on faith.

4. In the interests of all consumers a restriction should be placed on those not properly equipped to withdraw the contents without exposing the cylinder to damage by the introduction of water through back-siphonage (bleach manufacturers and the like).

5. License law is indicated for the chlorine consumer for the protection not only of the public at large in the matter of cylinder care, but also of the inadequately informed operator, who, through maloperation arising from lack of knowledge, may expose himself to injury, serious or otherwise.

1948 OPERATORS' FORUM *

RALPH E. FUHRMAN, *Chairman*
Superintendent, Blue Plains Sewage Treatment Plant, Washington, D. C.

Annual Operation Reports

C. C. Larson, Chemist, Springfield (Ill.) Sanitary District:—For about 12 years I published an annual operation report, but the report became a war casualty. It is still somewhat of a convalescent. The operation data are, however, summarized and classified just as if the report were being published, because the person who gets the most good out of the annual operation report is the man who prepares it. If anybody else reads it, that is just sort of an extra dividend. The report is of most value to the plant where it is produced. The vast amount of technical data, both chemical and physical, accumulated by sewage treatment works is not of much value unless it is summarized and made easily available. That, of course, is exactly what an annual report does. It permits one to find data readily without having to thumb through daily laboratory sheets and reports.

For whom is the annual report written? The answer might be divided into three categories: the general public; superior officials, the commissioners or trustees; and the members of the sewage treatment profession. Of course, the nature of the report will vary depending upon which of these three groups it is desired to reach.

As a general rule, the public is not interested in technical data. We are all aware of that. For this group, a descriptive booklet, written in popular language and containing many illustrations will serve the purpose. Such a booklet, of course, need not be revised very frequently.

The second group consists of the trustees or the officials. They are employers who are more interested in the financial aspects of the plant. Some of them will read the technical data, but they usually are not particularly interested in strictly technical information.

That leaves the third group, the members of the sewage treatment profession. My annual reports were always prepared with this group in mind, keeping the descriptive material at a minimum and emphasizing just the technical data.

As to the form of a report, an endeavor has been made to keep the report simple, well organized, but with a minimum of descriptive material. It is rather discouraging to receive a report whose pages are filled from top to bottom with single spaced, typewritten, mimeographed material. My tendency (and I suspect that I am not unique in this regard) is to lay such a report aside for future reading, and that time rarely ever comes. Inherently we are all a little lazy and will not read poorly organized and prepared reports; but unless somebody reads the annual report, much of its value is lost and the time spent in its preparation has been partially wasted.

In order to encourage people to read the report, a little window dressing must be used. It is desirable and advisable to dress up an annual report by including a good table of contents and index; by providing attractive format and layout; and by preparing data tables that are clear, concise, and not crowded. The matter of overcrowding is of prime importance in many reports.

In an effort to encourage the preparation of annual reports, the Federation offers three awards known as the

* From transcript, Twenty-first Annual Meeting of the Federation of Sewage Works Associations; Detroit, Mich.; October 18–21, 1948.

Hatfield Awards. The Board of Control is doing everything possible to encourage competition for these awards. The preparation of annual reports requires considerable time and effort, but they have definite merit and serve a vital purpose. This is evidenced by the many requests received from designing engineers, libraries, and other interested people, both in this country and abroad, for copies of my report.

Having been on the preparation end of reports for many years, it is rather gratifying to get an acknowledgment of a report. If someone just sits down and writes a card, it sort of flatters the man who sends the report, and in a small way it repays him for the time and effort put into the report.

All sewage works men should do a little missionary work and try to promote and encourage the preparation of annual reports. Bottle experiments are all right, but data coming from a plant in actual operation is infinitely more convincing and valuable. Annual reports are an excellent method of distributing that practical data to all who can use it.

Walter A. Sperry, Superintendent, Aurora (Ill.) Sanitary District:—I believe Mr. Larson missed one point which I have in mind about our own preparation of the annual report. I sometimes tell my trustees that if the report did not go outside of the District office, it still would be worth while. It is the duty of the superintendant to actually review carefully the year's operating data and prepare the report as a record of the year's accomplishment.

I am rather proud of the fact that 17 sets of blue prints now hang on the office wall. Each set contains a monthly and annual summary of the plant's operation. Another set is kept in the safe, because these reports are exceedingly valuable. Moreover, they are referred to often, as one forgets what has happened during the years and we try to get into the annual report every important occurrence during the year.

Now, one more point. When my board meets each month there has been prepared a 7- or 8-page report on the bills that also includes 2 to 4 pages of notes concerning what happened during the month. All my buying and selling is done in these paragraphs. When the board meets, about all I do is listen to their stories. Nothing has to be said, because it is written. The trustees come in, pick up the report, and take a little time to review it. Preparation of this monthly report is one of the best things done. In addition, each month the monthly reports are summarized so that at the end of the year the recasting of the monthly reports makes it a rather simple job to assemble an intelligent, valuable annual report.

Kerwin L. Mick, Chief Engineer and Superintendent, Minneapolis-St. Paul Sanitary District:—The Minneapolis-St. Paul Sanitary District is rather fortunate to be the winners the last two years of the annual operation report awards of both the Central States Association and the Federation. Some people feel that we put out a rather elaborate report, printed in a fancy manner, with many pictures. Actually, however, when considered on a yearly basis, an annual report does not require much work or expense. It is the best possible way of obtaining good public relations. In our own city, and elsewhere, it is about the cheapest form of public relations that can be employed. The report this year cost approximately $1 per copy, which adds up to a few hundred dollars for the copies printed. Not only is an annual report considered most valuable from the standpoint of public relations, but it is also found very valuable to ourselves and others as a reference source for everything that has taken place in the District. Continually reference is made to it to find out what was done in past years.

Without such a report it is necessary to thumb through the files. One will often forget that there is data in the files on an important matter requiring immediate attention.

Frank Woodbury Jones, Partner, Havens and Emerson, Cleveland, Ohio:—I have been working with reports for nearly 40 years and, although I hate to admit it, many reports still leave some things to be desired. Sometimes a problem comes up and one goes to the files for an old report, only to discover that the item on which information is wanted is always lacking.

The first thing necessary to writing a report is data: it follows naturally that the data should be authentic. One of the plants that we supervise was provided with a very simple arrangement for determining the flow, which could be calculated twice a day by measuring the rise in the dosing tank water level. At times the flow reported seemed quite accurate, but it was noticed that in the monthly reports there was a rather striking uniformity of flow. So, the plant was visited one afternoon at about the time the dosing tank measurements should have been made. When the monthly report came in a 6-in. rise in the dosing tank water level was shown for that particular day, but I know it was not measured. The operator never did understand why he was not supported when he came up for reappointment.

Recently I have been reviewing some old reports and have found memorandums without dates on them. Whenever you write a memorandum always include the day and year. I like Mr. Larson's annual reports because they carry a summary of data for several previous years.

There is another thing I would suggest in the preparation of reports: prove what you put down. Primarily the annual report is prepared for local use, but you would be surprised at how few operators will try to prove their own analytical work.

LeRoy Van Kleeck, Principal Sanitary Engineer, Connecticut State Health Department:—Mr. Larson, I believe, is correct in feeling that annual reports are not necessarily prepared for the public. However, in some of the small plants in Connecticut it has been worth while to show the operators how to figure, from the suspended solids and flow data, the tons of solids removed per year by the plant. Listing the total tons of solids removed together with the million gallons of sewage flow help the public to visualize the job the sewage works is doing.

To my mind the most important parts of the annual report are the yearly summaries. When you can look back and see how many tons of chlorine you used 5 years back, what the average flow was, what the cost per million gallons for treatment has been, the cubic feet of sludge removed from the digesters, and the amount of cake removed from the beds, you really know what the plant has been doing.

Morris Cohn, Editor, Sewage Works Engineering, and Chief of Bureau of Sanitation, Schenectady, N. Y.:—In addition to the annual technical report which all of us want and which all of us should prepare, there should be an occasional release of leaflet data for general distribution throughout the community. For years I prepared a highly technical report on the operation of the Schenectady sewage treatment plant, and it had its wave of popularity in our own profession, but seldom did anyone receive it with any particular interest in our community itself. At the end of 25 years of operation of the plant I prepared a popular brochure on the quarter-century of service of the sewage treatment plant, replete with a great many semi-humorous cartoons so that the subject matter was interspersed with enough eye-catching appeal to cause the reader to wade through it. That brochure was very quickly depleted, whereas other reports of the Bureau of Sewage

Disposal have been available for years. It was a brochure that told the story of sewage treatment in a very human way. I think we have to humanize our problem, and we must make sewage treatment understandable.

Digester Corrosion Problems

Lloyd C. Huffman, Superintendent of Sewage Treatment, Dayton, Ohio:—Our experience at Dayton with corrosion has been very limited. In 1944 we had been experiencing trouble with keeping the contents of the No. 1 and No. 2 digesters at the proper temperature. So, it was decided to clean out these two tanks. The grit found on the bottom of the digesters was about 3 ft. deep at the walls, sloping in towards the center of the tanks.

We found a ¾- to 1-in. sludge incrustation on the top of the hot water heating coils. Inasmuch as we had decided to increase the radiating surface, the coils were completely dismantled, cleaned, and checked. It was decided that the pipe was sufficiently good to be used again for the hot water coils so those pipes were returned to the tank. After 6 years of operation the tank has given no trouble as far as leakage from the coils is concerned.

Of course, a complete inspection of the digesters was made when they were emptied. We found absolutely no corrosion in the concrete or on any of the cast iron pipe. The skirt and rim of the floating covers were coated with a 1/16- to 1/8-in. film of grease, but there was no pitting and no corrosion that extended on up to the guide pipe. We have erected most of our own digester covers, painting them on the ground and painting them again after the welding is done. We take all possible precautions to prevent corrosion, and until the present time we have been very successful, or very fortunate, in not having any corrosion problems.

George E. Flower, Superintendent, Southerly Sewage Treatment Plant, Cleveland, Ohio:—At the Cleveland Southerly plant we have 12 separate digesters. We have had the digesters down twice in 10 years of operation, and both times have made a very good inspection of the covers. We noticed very little corrosion anywhere. A majority of the covers still have the original paint, which is still in good shape, on those portions not submerged in sludge. We have noticed a little corrosion on the upper part of the covers, which easily can be reached and painted. We have also painted the top of the cover, under the roof. This was necessary because of leakage of water at the top of the roof of the covering and because of a certain amount of condensation which resulted in a little rusting.

Where there has been welding the areas must be thoroughly cleaned before painting or the paint will provide little protection against corrosion.

John W. Johnson, Works Superintendent, Buffalo (N. Y.) Sewer Authority:—I am quite interested in hearing about the corrosion between the roof covering and the steel ceiling plate of the floating covers. We have entered our digesters many times and have not found corrosion within the digesters, although we have had trouble with the wood roof covers. After the roofing on one cover became so badly rotted it had to be replaced, we provided a series of ventilators around the outside edge and exhaust vents at the center. After painting the upper side of the cover plates the cover was insulated by blowing rock wool in between the cover plate and the wood roofing. This insulation has been very effective for 3 years in preventing loss of heat through the digester cover.

Charles C. Agar, Senior Sanitary Engineer, New York State Health Department, Albany, N. Y.:—I believe that some of the experiences we have had in New York state may illustrate that it is possible to have corrosion trouble in sludge digestion tanks.

Corrosion is not confined to the action of particular chemical materials, for example hydrogen sulfide, on worn metal surfaces. It may also be due to the electrolytic galvanic action between various metals and various alloys of metals.

The experience we have had with some plants in the North Central part of the state would indicate that there has been considerable corrosion of the metal equipment within digestion tanks. I cite as an example a plant which has been in operation for 10 years. During that period the replacement of the digester heating coil was necessary on two occasions due to corrosion which resulted in breaks and holes in the pipe.

That experience led to the investigation of other tanks that had not been inspected. It was found that corrosion did not occur in accordance with any standard pattern. One of the engineers attempted to make a study of this situation, and by testing with sensitive volt meters he has obtained differences in potential amounting to as much as 0.4 volt. It is possible that this may be a factor in many plants.

I dare say that we do not yet know the whole story about the number of plants that may be undergoing some form of corrosion. It must be remembered that many of these sludge digestion tanks are comparatively new. Many of them have not been inspected. I know some have never been emptied or checked for 18 years. No one knows what the condition is inside until some serious difficulty arises. I know that we are going to secure the cooperation of the equipment manufacturers on further studies and investigations concerning reasons for corrosion, because it affects them from the point of view of maintenance of their products. I think one of the factors to be considered is the need for more emphasis on preventive maintenance.

Arthur H. Niles, Superintendent of Sewage Disposal Division, Toledo, Ohio:—The Toledo plant has been in operation more than 16 years and we have emptied digesters several times. The first time was 5 or 6 years ago and the last time was in the winter of 1947. At that time we found no corrosion of the heating coils. These coils are made of Armco cast iron welded pipe. The hangers were intact and the malleable ironing hangers and inserts, together with the rods, were in perfect condition.

The digesters are the fixed cover type, with the stirring mechanism having conventional forearms, two of which have scraper blades with the long, sloping channel that reaches from the central column out to each of the arms. Those 8-in. channels were in excellent shape, the original erection numbers still being readable after 16 years. However, some of the smaller members, particularly the channels, on the cross bracing between the arms were quite badly pitted. In fact, some of them had a hole right through the corner of the channel. This would mainly occur, not at the connections, but possibly 8 or 10 ft. from the connections. On the vertical angles there was practically no corrosion. It was present only on the horizontal members, and they were in rotation so that they would not be in contact with this same material.

We could only theorize that there may have been a difference in the steel used in the various parts of the equipment. These mechanisms were fabricated by the American Bridge Company shop in Toledo, which was later moved to Ambrose. Of course, the original records were lost after that length of time, so we had no way of knowing whether all the steel had been open hearth steel, or whether some of it might possibly have been Bessemer converter steel. Our theory is that in the Bessemer steel some of the impurities, such as sulfur or phosphorous, may not have been removed and that

these may have been responsible for the pitting action.

L. S. Kraus, Chemist, Greater Peoria (Ill.) Sanitary District:—In connection with Mr. Niles's statement that the horizontal surfaces were corroded and the vertical surfaces were not corroded, we had a similar situation in the gas holder. The bottom of the gas holder started to leak. We found all the vertical surfaces and the roof of the floating cover in excellent condition, but the bottom was practically gone. All the horizontal surfaces of the angles were corroded, although the vertical surfaces were in excellent condition. We have no explanation for it, but in connection with the statement Mr. Agar made, we found there is a definite potential between the lift of the holder and the water seal tanks. We grounded the water seal tanks in the hope that it would reduce the electrolytic action.

Mr. Larson:—We have operated the first commercially built digester floating covers installed in this country. The first experimental covers were developed at Plainfield, N. J. Our floating covers were built in 1929 and are still performing satisfactorily.

We have had occasion to enter these tanks several times for cleaning and other reasons, and have never found any evidence of corrosion on the underside of the cover. Knowing that the subject of corrosion was to be discussed here, I brought along a small disc, or "coupon" as they are called, which was cut from one of the covers. Eleven years after the covers were installed we decided to put a couple of thermometer wells in the covers. We bored 3-in. holes for this purpose and I saved this plug which came out of the top of one cover. The outside surface, which was painted and walked on, is somewhat rough; but the inside surface, which was the ceiling of the digester and supposedly exposed to digested sludge, is very smooth. It is rather difficult for me to conceive of much oxidation going on inside a digester where, supposedly, there is a complete absence of oxygen.

Mr. Van Kleeck:—I do not understand why we have electrolytic action in digesters. I do know that at New Haven after 8 years of operation the heating coils are leaking. They have set up tests that show that electrolytic action in causing the corrosion. I understand from the superintendent that they plan to protect the tanks when they are returned to operation and that the cost of the protective equipment would be about $400 per tank. At another plant in Connecticut, which has now operated 20 years, there has been no trouble with leaking coils.

C. T. Mudgett, Superintendent, Muskegon (Mich.) Sewage Treatment Plant:—We examined a digester last winter and found the metal work in very fine shape, a leaking heating coil being the result of a construction mistake at the time of installation.

The digester cover was found to be in good condition and there was no corrosion on the under side. There was some corrosion, however, on the upper side of the cover plates between the cover and the wood roof covering, where condensation and leakage had occurred. This corrosion can be controlled by proper painting. With reference to the corrosion and leaking of digester heating coils, which has been referred to by previous speakers, I am wondering whether or not that corrosion took place from the outside of the pipe, or from the inside? We have not had corrosion of the digester heating coils, but in the heating system in the service building there has been corrosion, which has developed from the inside of the equipment out.

Mr. Van Kleeck:—At New Haven the corrosion was from the outside in. Also, I might add that at New Haven salt water and industrial dye wastes occasionally entered the system. This may have some bearing on the problem.

Chairman Fuhrman:—Was it the coupling or the pipe that failed?

Mr. Van Kleeck:—The pipe was joined at the coupling.

Mr. Agar:—In all cases in New York the corrosion of the heating coils was from the outside in. There was generally no particular spot where it occurred. In reference to the question of electro-galvanic action in the digesters, there is a difference in potential between the hot water pipe entering and the cold water pipe leaving the digester, which is caused by the temperature differential.

In regard to digester covers, I just inspected a plant where there is serious pitting of the underside of the cover along the water line. That cover has been in service for 7 years. At another plant the floating cover was corroded seriously at the lift around the skirt of the cover.

Mr. Davenport:— We have two digesters with floating covers. About 2 years ago we drained the digesters because of leaking heating coils. There are eight coils in each digester supported by structural steel pipe hangers located approximately 10 feet apart. All eight coils were corroded between two pipe supports, although there was absolutely no corrosion between pipe supports on either side of this section or for approximately the same distance around the tank. There were other sections, however, where all the coils were corroded between a pair of pipe supports without corrosion being evident between adjoining supports. The covers had some pitting, undoubtedly due to a defective protective coating.

The corrosion on the coils appeared to be in the form of barnacles, beneath which there were deep pits that appeared to contain clear water. I thought that perhaps this corrision was due to the anchor shields attached to the pipe support in the wall coming in contact with the reinforcing steel and thereby setting up an electrolytic circuit. The pipe coil can be insulated from the pipe hanger by using a rubber band around the pipe.

Maintenance of Electrical and Mechanical Equipment

Mr. Flower:—The maintenance of mechanical and electrical equipment is a very considerable problem. Today the modern sewage treatment plant is almost completely mechanized. Our Cleveland Southerly plant utilizes over 300 electric motors, ranging in size from a fractional horsepower up to 150 horsepower. We operate more than 100 pieces of mechanical equipment. Of course, constant maintenance is necessary for continuous operation.

The first requirement for satisfactory maintenance is to have a well equipped machine shop—even to the inclusion of welding equipment, lathes, drills, and the like. Personnel competent to operate the machine shop equipment are also necessary. At Cleveland we are fortunate enough to have personnel of all classifications.

The next requirement for satisfactory maintenance is the provision of secondary or stand-by units for the mechanical equipment. Of course, this is impossible for the larger units, but it can be done for the smaller ones. An adequate supply of spare parts should be maintained. When a new unit is installed, write to the manufacturer and get a list of the spare parts. Also ask him what parts he recommends keeping in stock, as he is more familiar with the equipment and knows what wears out much better than you do. After the equipment has been in operation for some time, you will find out which parts are wearing out and which you should stock.

Lubricant is another item that is very important. The best obtainable is the cheapest. Some municipal purchasing departments buy on a cost basis and you do not get a good lubricant that way. We have had many arguments with our purchasing department. We write up an order specifying

a certain lubricant that we know will do the job, even listing the company's name. Then the purchasing department sends the requisition back and tells us that we can't do that. As a result, an inferior lubricant is obtained and the equipment bearings suffer the consequences.

We have conducted a series of tests on gas engine lubricating oil. The results indicate that in gas engines, oils containing a detergent give the most satisfactory results. A regular greasing schedule should be established and maintained. We have assigned to that work one man whose only duty is to keep the lubrication schedule up to date. When electric motors are lubricated, the drain plug is removed before forcing in the grease, because the bearings should not be put under pressure. A motor should run for a short time after greasing to allow the lubricant to heat up and expand before the plug is replaced.

We also have what may be called a "new order" record sheet, generally made out in duplicate. This record sheet is distributed to the principal parts of the plant, and indicates when the report is made out, the name of the unit, the cause of the stoppage or breakage, the date and the time, and the name of the operator. Each morning this sheet is picked up and taken to the superintendent, who examines and studies it and then assigns a workman to make the repair. This workman generally makes the repairs immediately, or as soon as other or emergency work will permit. The record sheet is then returned to the superintendent and placed in the file. However, if the trouble continues or occurs too frequently a more complete inspection is made to determine what is really causing the trouble.

Considerable trouble developed with our 400-ton incinerators. The rabble arms were bending down from the heat. It was thought that perhaps the wrong type of alloy had been used for the arms, as they were supposed to be of a high-temperature alloy steel. I discussed this with the manufacturer, who discounted this possibility. The company that made the steel for the arms was located, and rabble arms were ordered of an alloy steel containing 35 per cent chrome and 12 per cent nickel. These arms have proved very satisfactory. Tests of the old arms showed that the chrome content was only about 25 per cent and that there was very little nickel content.

The mufflers on the exhausts of our Copper-Bessemer gas engines became corroded or burned out from the exhaust gases. This happened during the war period, when it was extremely difficult and costly to obtain this type of equipment. The old mufflers were removed and replaced with a straight piece of pipe, flanged at both ends, of the same diameter as the exhaust pipe. The last section of the replacement pipe was then cut on a diagonal for a distance of 12 times the diameter of the pipe, or in this case 120 inches. This arrangement has worked so well, so quietly, and with so little back pressure on the exhaust gases, that I do not intend to install the old type of muffler.

Mr. Huffman:—It seems to me that a completely equipped machine shop is a questionable investment for a majority of sewage treatment plants. Local machine shops in Dayton are equipped to make anything. Therefore, we have arranged with a local shop to do our necessary repair work on an emergency basis and have had very good cooperation. We spend less than $2,000 per year on such repair work, and I am quite sure we could not equip and operate a machine shop at the plant for that amount of money.

H. V. Crawford, General Electric Company:—In talking about mechanical equipment, the electrical equipment usually is an afterthought. The maintenance of electrical equipment is, of

course, highly important. It is the real heart of the plant.

The way most electrical equipment is maintained is rather similar to the way our wives operate our automobiles. They think that all that needs to be done to an automobile to keep it running is to add gasoline. Electrical equipment generally does not give any advance notice of impending break down. As long as a motor runs without unusual noise it is assumed is doesn't need attention.

The most important thing about the electrical equipment is the selection of proper equipment. Many electrical concerns build good equipment. The choice as to the type of motor, enclosure, and wiring needs careful attention. Most sewage works men are civil, mechanical, or sanitary engineers and, therefore, the electrical equipment is more or less an afterthought. During the war there were several cities that did not have electrical maintenance troubles; they did not have to shut down because of a lack of spare motors or parts. Many of those people when they purchased electrical equipment followed the custom of asking advice as to what parts would require the most frequent replacement. When one of our municipal customers purchases electrical equipment, an extra set of coils is ordered for every three motors of similar size, design, and characteristics.

Proper installation of the equipment is also important. Plenty of space should be provided around the equipment and the controls should be located in a separate room, if possible. Cabinet controls should be installed away from the wall and should not be placed in rooms exposed to gases and high humidity. We have recommended that electrical controls be assembled in cabinets. A small heater should be installed in the bottom to maintain the temperature inside just a fraction of a degree above the room temperature. This keeps the inside of the cabinet warm enough so that corrosion does not take place. When the control cabinets are located against walls it is not necessary to have water running down the wall or to have steam dripping down the back of the cabinet in order to have serious corrosion trouble. Dampness inside the cabinet is all that is required to accelerate corrosion. Proper selection, installation, and inspection of electrical equipment will eliminate maintenance and repair troubles.

Proper lubrication of bearings is important. At one installation a motor ran for 3 years without any lubrication. Finally the motor failed. Examination revealed that the grease drain plug had been removed, but that the maintenance man had blocked the opening. The operator had been trying unsuccessfully to shoot grease into the motor for a long time.

Mr. Cohn:—Mr. Flower, I believe, is absolutely right in urging that some plants have machine shops. On the other hand, it may be a waste of money and be a very impractical procedure to have a small plant completely fitted out with a machine shop. The thing to do is find a dependable privately owned machine shop somewhere in town and learn what it can do for you. Have them learn what your problems are and then give the work to them as the occasion arises.

I am reminded of a story about Henry Ford and the D. T. & I. Railroad. When Henry Ford bought the line, in his usual methodical manner he made a thorough personal inspection of the shops. He came to one spot in the shop where he found a man welding the coils in a steam locomotive. The fellow was virtually standing on his head. Henry Ford said to the supervisor of the section, "Would it not be more convenient for this fellow if he could stand upright in a more comfortable position and do his work?" The supervisor, being a "yes" man,

said, "Sure, I think it would be a very convenient and desirable thing."

Henry Ford returned to his office and turned over to his engineering department the job of designing a very ingenious cradle which could pick up a locomotive and turn it over on its side in any direction so that a welder working on the job could stand upright. They built the device at a cost of $40,000. When it was ready for operation Henry Ford asked the same shop supervisor "Will you tell me how much work you have of this nature?", to which the supervisor replied, "Well, last year it amounted to about $400 worth." I believe you have to be very careful that you do not buy yourself a "locomotive tilting device."

Wade D. Brown, Chemist, Durham (N. C.) Water and Sewer Department:—It is true enough that the best lubricant you can buy is the cheapest, but it struck me also that it cost my plant and municipality money to go into the problem of finding out which is the proper lubricant. We found that the lubrication manufacturers are very willing to send a lubrication engineer to make a survey of a plant and recommend the proper lubricant for any piece of equipment. They will also send a representative to instruct plant personnel in the proper procedure for lubricating motors. Too much lubrication can be just as harmful as not enough.

The maintenance of electric motors presents a great problem in a plant that uses several hundred of them. We know that a majority of municipalities buy new equipment strictly on a cost basis, but it should be of primary importance to every plant superintendent to insist that there be a standardization of motors and electrical equipment within the plant. I know that there are several plants that have motors of the same horsepower and speed, but made by a half-dozen different manufacturers. It is impossible to keep a supply of bearings or coils for the maintenance of all makes of motors. All plant personnel should be given a course of instruction in routine lubrication and inspection practices.

Mr. Flower:—When we started the Cleveland Southerly plant we called in the different oil company representatives and asked for their recommendations. We followed their recommendations very closely—but we found that they also make mistakes.

Chairman Fuhrman:—Mr. Flower previously mentioned the problem of getting the desired lubricants when purchases are made on the basis of competitive bids. Purchasing officers have their rules to follow and our problem is sell them on the idea that we need particular grades of lubricants. We should not have to sell a purchasing officer on the fact that we need a certain company's product. Rather we ought convey the idea that we need a lubricant that meets the specific specifications and service qualities which the desired "name" lubricant possesses. Federal specifications are used in this way.

Public Relations

Mr. Johnson:—We are all acquainted with the fact that the subject of public relations is a most important one from the operator's point of view. When the public pays its tax bill without grumbling, that makes our job of building, operating, and improving treatment plants a great deal easier.

We have been very fortunate in the fact that during the last several years the non-technical press of the country has taken up the cause of pollution abatement, which so long has been advocated by this Federation, our technical writers, our editors, the U. S. Public Health Service, and the various state departments of health. Daily accounts of the need for more adequate pollution control appear in the public press. During the war years the large population migrations and resulting overcrowding of many areas empha-

sized the almost universal need for more adequate sewage and industrial waste collection and treatment.

During the last session of Congress, a federal water pollution control bill was passed, and it is apparent that additional legislation will be effected by Congress in the future. By such action stream pollution control will be held up to public scrutiny for some time to come. Many state and local governments in the last 2 years have enacted measures for stream pollution control or will do so in the immediate future. All of this activity creates a great amount of publicity for our profession. Much of this widespread interest began in the local communities through the efforts of farsighted sewage works operators. They have seen fit to render efficient service to the taxpayers and to publicize that service by inviting the public to view their plants. They have drawn attention to the before and after conditions of receiving streams and have informed the public of the benefits to be derived from this work.

As never before the door is open for securing the public's good will, but this good will must be earned and must be cultivated and maintained because the public is often unreasonable when it is uninformed, and it is quick to forget. It behooves sewage works men to keep and expand the existing favorable public endorsement of stream pollution control activities.

Robert A. Greene, Superintendent, Jackson (Mich.) Sewage Treatment Plant:—We have at our plant a well satisfied operating crew, which is one of the biggest assets in selling a sewage treatment plant to the community. Our plant site consists of a 55-acre plot of ground, about 30 acres of which are in park area equipped with 35 picnic tables, a baseball diamond, and a camp ground. From 75 to 100 people a day visit the park during the picnic season. That is why the attitude of our plant operators is important as the plant operator is the person the visitor sees.

In our park there are two lagoons, which we have stocked with ducks, Chinese swans, and other types of animal life. These have proved to be quite an attraction to children and parents and are another way of selling our sewage plant to the public. We also distribute to plant visitors a little pamphlet describing our plant and the purpose of each different part of the plant in the simplest of layman's terms. It is much appreciated by them and we believe it has been worth while.

Leslie E. West, Chief Engineer, Joint Meeting Sewage Treatment Works, South Orange, N. J.:—The point I would like to bring out is that of broadening the attitudes of the engineers and plants operators towards their communities. Taking active interest in community affairs will help to do this. By affiliating with service clubs and other local organizations plant operators can increase the community understanding and appreciation of their work.

Of course, there are other ways in which this can be done. If a plant operator is interested in his plant he can develop an informative talk on the history and operation of his plant for presentation before various community groups. He can also keep himself available to assist people with all types of waste disposal and sanitation problems. Cooperation with the local press in providing interesting information about the sewage plant will pay rich dividends.

Mr Jones:—How different things are from what they used to be. I can remember going into many towns where no one seemed to know, or care, where the sewage treatment works was located. In my early days in the sewerage game, we would watch for a state inspector to come for an inspection, and instead of trying to acquaint him with our problems and difficulties, we would do our best to keep him from finding out about them.

An entirely different attitude exists

now. As far as I know, almost all plant operators welcome a visit from the state health department engineer. That is just as it should be. It is my observation that the men employed by the various state departments know their job. They visit plants with the idea of being helpful. They understand an operator's problems and difficulties and try to help him solve them. There is growing understanding and cooperation between municipalities, plant operators, and the state officials. I think it is something that should be most highly commended.

Mr. Cohn:—I am obliged to say something apropos of what Mr. Jones just stated because I think there has been a very definite change in the tenor of our own people and in the tenor of public opinion. I speak from some 27½ years of experience that goes back to the early days when there was little interest on the part of the public in sewage treatment. This may have been caused in large part by our own attitudes. We get no more respect from others than we have for ourselves.

First of all, we must build a greater respect for our own profession—not only for our inherent knowledge of plant operation but also for the fact that the collection and treatment of the liquid waste of community life is an important link in the public health chain. When you view it that way and present the subject locally in that light, you gain a better recognition from the public than you could possibly get by talking only about the sheer mechanics of treating sewage.

There is one thing which has happened to me recently that most of us may have felt. If the repercussion of it has not hit your community, it is bound to do so. It is this: the sudden interest on the part of youth in the problems of city government. Be assured that this interest is not superficial. The young people are anxious to know many of the details which are of little interest to the average adult. Nevertheless, this interest does not spring spontaneously from the minds of youth. It is being cultivated through public educational systems by courses which bear the rather euphonious title of "social studies" or "social science." I am sure a great many of you either have been asked to talk to classes in social studies or have had such classes request permission to visit the treatment plant. This is a wonderful opportunity for bringing home a message, not only to the youth of America, who are the future taxpayers, but also to the home because children bring home to the dinner table at night the things they see and do during the day. It is surprising how much influence youth has in the home. It is pretty much the practical application of the philosophy that "a little child shall lead them." If you are sincere and generous in your contacts with the young people of your community, you can arouse their interest in the problems of sewage and waste disposal.

Sol Seid, Supervisor of Public Works, New Brunswick, N. J.:—At New Brunswick we have a youth week, previous to which there is a two-week period when representatives of every department of the municipal government speak to the high school seniors. Following this two-week period these seniors elect about 15 candidates for municipal offices. They take office for one day, and you would be surprised at the interest these young people have. We take all of them through the branches of the municipal government and when they go back home they sell their parents.

It is up to us to go out and speak before civic groups and chambers of commerce. Where you have a local radio station, take it upon yourself to go to the manager of the station and arrange for time once a year to report on your municipality's waste disposal system.

Paul Molitor, Jr., Superintendent,

Joint Meeting Plant, Rutherford, N. J.:—We feel it is important at our plant to stress cleanliness. When we have visitors, naturally the first thing that meets their eyes is the appearance of the plant. We do not dress up the plant for visitors, but we try to keep it clean 24 hours a day. Our operators are instructed as to how we want it kept and we insist that they comply. In addition, we do not forget the fact that we are public servants. We insist on the utmost courtesy at all times towards all visitors.

Mr. Larson:—I do not believe there is a better opportunity to exercise good public relation practices than in answering complaints. Those of you who have had charge of plants or have acted in an administrative capacity know that there is nothing quite so formidable as an irate housewife on the telephone. If you do have an answer for complaints, fine; but you often get yourself backed into a corner. I have found it well to sympathize with them and listen to their story even though you do not know the answer. After all, what they really want is a little sympathy, and instead of adopting a defensive attitude or a chip-on-the-shoulder attitude, just admit that you do not know the answer to the problems, but that you will do all you can. Such an attitude will go a long way toward pacifying complainants.

Protective Paints and Coatings

William D. Hatfield, Superintendent, Decatur (Ill.) Sanitary District:—In painting, the important thing is getting the prime coat to stick. Having a good prime coating on new equipment, followed with a good secondary coat of paint, is one thing, but it is different when you have a piece of apparatus that is pitted and corroded and you try to get a prime coat on it that will stick on the old, rusted iron.

For a number of years we have used a preparation which helps to dissolve or loosen the rust so that a week or more after the application the rust can be brushed off much more easily than before. This material, called "Consol M" and made by the Intercoastal Paint Company of East St. Louis, has been very helpful in cleaning up old, rusted steel mechanisms. The chief difficulty is that it does have to be put on and left to soak in, preferably for a month. This compound is used to spray steel decks on ships, and similar surfaces which are difficult to paint. It has rust preventative properties.

Over the past 20 years whenever we have painted a Dorr mechanism or any other under-water mechanism in our secondary treatment units, each arm has been painted with a different kind of paint. We have concluded that old rusty steel structures should be treated with the "Consol M," allowed to stand at least a week, and then brushed thoroughly. The arm may then be painted with coal tar paints of the Inertol or bitumastic types. These will hold up for 2 or 3 years. Much better results are obtained with synthetic resin type paints such as Bakelite, chlorinated rubber, and Vinylite. These coatings should last 4 to 5 years, but a 2-year inspection followed by spot painting is most satisfactory.

Last year we tried treating the wire brushed steel with Inertol's phosphoric acid inhibitor No. 33 and following it with the above paints. After 1 year of service the indications are that the phosphoric acid treatment may have some advantages. The results all looked better than usual for the 1-year period.

C. E. Drummond, Jr., Wiedeman and Singleton, Atlanta, Ga.:—I would like to suggest that perhaps some of the consulting engineers in the profession might be glad to contribute what they know about the matter of the paints. The engineering profession is almost a matter of the use of protective coatings. A consulting engineer has to answer to the plant operator when the protective coatings seem to break down.

There is quite a bit of misconception concerning how different types of paint coatings will withstand atmospheric conditions. One thing which is not often pointed out is the fact that all ordinary coatings are of absolutely no value in preventing the entrance of moisture to the steel surface. If there is moisture present or the equipment to be painted is submerged, a bituminous coating must be used.

It is suggested that the prevention of rust is extremely important. Not long ago I consulted a structural engineer in Atlanta who has designed a large percentage of the steel frame office buildings there. He advised that over a long period of time not even 4 in. of brick work was effective in preventing the rusting of steel frame work of buildings. Rusting had become so serious in a number of large buildings that he is now requiring 8 in. of masonry for steel frame buildings.

Harry E. Schlenz, Vice-President, Pacific Flush Tank Company, Chicago, Ill.:—I am not talking from the standpoint of the plant operator but from the standpoint of one supplying equipment and wanting to see that it is properly protected. Years ago we were able to get plenty of steel from the mills. Steel lay out in the fabricating plant yard long enough to have it rust. After fabricating it would be wire brushed, then painted with a prime coat. Now when the steel comes from the mill it rusts, is fabricated, and is painted before the mill scale loosens up. If we put a protective coating over the mill scale, the scale later breaks and takes with it not only the field coat, but also the shop coat.

We have tried to have engineers specify that large steel structures be shipped to the jobs unpainted. Although the steel looks quite badly rusted by the time it is used, it is only the mill scale that is rusted. A proper wire brushing will take off that mill scale and give a good clean surface to which the paint will stick. However, specifications have been based on the old way of doing things and it looks so good to send steel out with a nice red oxide coating, which really does not give protection on the job. On the larger projects the steel should be sent out unpainted, with the surface thoroughly cleaned and the protective coatings applied at the job site.

Van P. Enloe, Superintendent, Clayton Sewage Treatment Plant, Atlanta, Ga.:—I was interested in what Dr. Hatfield had to say concerning the phosphoric acid treatment because a good many of the steel fabricators are using that method before the steel is shipped, and nothing more is done to the steel until it is on the erection site.

We all know that iron oxide is nature's scab for iron and steel products. In the water works industry there has been considerable success at various places with the application of a grease type of protective coatings, applied with a spray gun in order to reach all the cracks and crevices. The oxide does not seem to prove troublesome because with the grease covering it acts somewhat as a protective coating itself. I am wondering if anyone has had experience with these types of coatings at sewage works.

Dr. Hatfield:—You probably are referring to the Texaco wax-grease paints. I guess the best one is the oxide type, but there are others that have essentially the same specifications.

Fred H. Burley, Engineer of Sewage Treatment, Detroit, Mich.:—We have used two types of these wax-grease paints. One is the paint furnished by the Texaco company for use in wet locations. I observed the use of this type of coating on motor vehicles shipped overseas during the war. The grease coatings held up for months after the overseas transfer, provided too much abrasion was not encountered.

We are trying that kind of wax-grease paint at locations in the plant where we have pipes exposed to moisture. Another type of preparation is for interior surfaces of hot water tanks.

Various grease paints are recommended for service within reasonable temperature ranges. We were a little skeptical about the use of grease-paint, but we lined some of our hot water tanks with that material and, although we had previously experienced various degrees of corrosion, this wax-grease paint had the faculty of working through the rust down to the metal, preventing further corrosion. We have always had a very severe corrosion problem on these heavy tanks, which are submerged in a bath of water. The hot water system is an open system and there is considerable absorption of oxygen at the surface.

Metalizing is another means of preventing corrosion. We have used several kinds of metalizing sprays to see which stands up best. Unfortunately, we have not had these in service long enough to report on them at present.

Chairman Fuhrman:—The Texaco product Mr. Burley referred to is Rustproof Compound "L." At the District of Columbia plant we found this coating extremely useful in protecting difficult places.

Dr. Hatfield:—The outside type of wax-grease paints have not held up at Decatur, probably because of the high temperature—85° to 90° F.—of the raw sewage. Grease does not stay on the equipment.

Ordinances for the Control of Sewer Usage

Van P. Enloe, Superintendent, Clayton Sewage Treatment Plant, Atlanta, Ga.:—Somewhere between those who want their streams with pristine purity and those who would bring industry into an area without regard to its effect on natural resources, there is a happy medium that is fair to both sides. Likewise, in the use of public sewers there is a limit to the damage a waste can be allowed to do to the sewers, as well as a responsibility to dispose of all waste in some way. Any sewer ordinance, therefore, should strike the happy medium that will protect the municipal sewer system and at the same time provide for reasonable sewage service.

A subcommittee of the Federation's Sewage Works Practice Committee, in preparing a Manual of Practice on ordinances, has written a preliminary draft of a model sewer use ordinance, on which I do not think I can improve. Important among the provisions of this ordinance are those concerning the quantity and characteristics of industrial wastes that will be allowed in the municipal sewer system, as well as those governing construction, maintenance, and inspection of connections and sampling manholes, and those allocating the authority for control. These major divisions of the model ordinance may provide a guide for discussion of this important subject.

Mr. Cohn:—Some 15 years ago I went before the Federation and various state associations pleading for the inclusion of properly ground food wastes in the sanitary sewer system. Now the idea of grinding food wastes in the home and discharging them into the public sewer is beyond the realm of conjecture. In my opinion there may be now in use, and connected to public sewer systems, some 300-odd thousand such household devices, manufactured by 18 different companies.

I would judge that during 1948 there may have been sold and placed in service better than 200,000 units of this type. I know of one manufacturer alone who probably will produce and market 100,000 such units during the course of 1948. Household food waste grinders must be recognized as a factor in modern sewage treatment.

I would like to give you my own thought on what should be done to control the nature of the material discharged through home grinders into the public sewer system. There is a happy middle ground in controlling the nature of this material. It should be neither too coarse nor too fine. We certainly do not want to make colloids of food wastes, because colloidal ma-

terials pose sewage treatment problems more difficult to solve than those arising from suspended solids. Here are some simple specifications for ground garbage from home waste grinders: 100 per cent should pass a ½-in. mesh screen, meaning that nothing greater than ½-in. size is discharged from grinder; 90 per cent should pass the ¼-in. mesh so that there is uniform grinding; and not more than 5 per cent should pass a 40-mesh sieve. Screens should be U. S. Standard and weight should be on a dry basis. These specifications may be subject to modifications. They are presented because of the need for controlling the nature of material discharged by home food grinders.

Mr. Seid:—In 1944 New Brunswick established a sewer-use charge for domestic and industrial users. Sewer charges were billed separately from the water bills, which was a mistake. It is a peculiar thing that when a taxpayer gets his water bill he takes it as a matter of course, but when he gets a sewer bill, that is different. The idea of sending out separate bills was not good. I would suggest that in writing sewer revenue ordinances it would be wise to provide for the collection of the sewer charge by combining it with the water charge, and sending one bill. This will cause less dissatisfaction among the taxpayers and make collections easier.

Mr. Jones:—The subject of control of sewer usage is going to be very important in the next few years. There is a division of opinion as to whether anything should go into the sewers except domestic sewage. Some contend that the sewers are public property built for the use of the people and, therefore, everything should go in. It has been my unfortunate experience to see, where that philosophy has prevailed, a sewage treatment plant ruined almost overnight by an overwhelming industrial waste load.

A large proportion of the sewage treatment plants constructed in the next 10 years are going to be financed on a revenue basis. That means that everyone is going to have to pay his proportionate share. Industry must not be penalized, but neither must the ordinary taxpayer be made to pay the burden industry should carry. There is going to be a proper middle ground as to the collection of sewer rentals.

Alvin B. Backherms, Principal Engineer, Cincinnati, Ohio:—A comprehensive survey of the Cincinnati sewer system revealed 60 to 70 sewer outlets discharging directly to the Ohio River. It also disclosed that the sewage solids concentration was the highest of any large city in the country. Knowing the industries in Cincinnati, we concluded that many were not complying with the existing sewer ordinances.

The City Council's takes the attitude that industry should not be unduly penalized, but that existing ordinances should be enforced. Industry is requested to provide pretreatment when the character of its wastes requires it. Otherwise the wastes are admitted to the sewers and a surcharge based on the character and quantity of the discharged waste is applied to the regular sewer charge.

A sewer rental ordinance was passed in May 1948 and to date collection experience has been good. At first, delinquent accounts ran as high as 10 to 12 per cent, but they soon dropped to 1 to 2 per cent.

There have been few complaints or protests about the sewer rental charge. With over 120,000 accounts we have received only about 25 actual protests and about 600 complaint letters. The ordinance gives the taxpayer every opportunity to present his case. Complainants are advised to pay their bill and to attach a written complaint to it. They are listened to courteously and every effort is made to give them personal attention, all complaints being promptly processed and investigated. Perhaps you are too optimistic, but so far the sewer rental ordinance has been more than satisfactory in Cincinnati.

OPERATING PROBLEMS FROM TANNERY WASTES AT BALLSTON SPA *

By William Porter

Superintendent of Sewerage and Sewage Treatment, Ballston Spa, N. Y.

Litigation arising from stream pollution due to drainage of trade wastes from a local tannery and to the discharge of untreated sewage from the village resulted in construction, in 1905, of a sewage treatment plant by the Village of Ballston Spa, N. Y. As the 1-m.g.d. treatment plant was designed to handle only domestic sewage, the tannery wastes were excluded. In 1906, however, permission was granted for the tannery to drain its wastes directly into the village sewer.

The original treatment plant consisted of a lift station having a 2-compartment, 250,000-gal. receiving tank and bar screens, from which the sewage was pumped through a 2,700-ft. force main to a 3-compartment septic tank whose effluent was given a 2-hr. contact period in a primary stone contact bed, a like period in a secondary stone contact bed, and then discharged directly to the nearby stream. This plant treated both the domestic and tannery wastes to a more or less efficient degree for 2 or 3 years, after which the main plant was closed down and all flow was by-passed directly from the pumping station to the stream.

Reconstruction of Plant

In 1936, efforts of the State Department of Health and receipt of a P.W.A. grant brought about the first major repairs and improvements to the treatment plant. At that time straight-line collectors were installed in the receiving tank at the pumping station, making possible the daily removal of settleable solids and the pumping of fresh sewage directly to the settling tanks at the treatment plant. At the same time, the cover of the septic tank was removed, making available three rectangular tanks, 105 ft. long, 30 ft. wide, and 15 ft. deep. The first two were converted into primary settling tanks. The third was designed as a secondary settling tank, to which was passed the effluent from the first two tanks and in which straight line collectors were installed for daily removal of solids.

Two of the original secondary contact beds were remodeled as a trickling filter with a traveling type distributor. A secondary clarifier was also constructed.

These improvements were completed late in October, 1936; the plant was in full operation November 4, 1936. The writer operated this plant for 5 months, after which the plant was placed in the hands of others. This condition prevailed for approximately 2 years, during which time sheer neglect and improper operation caused the plant to suffer every type of deterioration. When the writer returned to the plant in May, 1939, the effects of improper operation had to be overcome and an extensive study of trade wastes started again. After placing the plant in workable condition, attention was given to the grossly polluted character of the outlet stream.

Interceptor Cleaning

The old 20-in. intercepting sewer seemed to be wholly inadequate and incapable of accommodating the trade wastes from the tannery. As a result, these wastes spilled into the smaller streams traversing the center of the village, the resulting odors being readily detectable in almost every section

* Presented at the 1948 Spring Meeting of the New York State Sewage Works Association; Niagara Falls, N. Y.; June 4–5, 1948.

of the community. A blind man could recognize Ballston Spa by its odor.

Investigations of the 20-in. intercepting line showed that the trade wastes (composed of hair, animal fats, and the various ingredients entering into the processing of leather), together with sand and street wash, left a deposit in the bottom of the line. This resulted in surcharge of the line during those periods when the tannery waste flow was high. The surcharging of the line resulted in stalactite-like sewer growths, which attached themselves to the crown of the sewer and by gradual growth materially reduced the line's capacity.

It was obvious that frequent cleaning of the sewer was necessary. There were no manhole openings in this line, which was 5,478 ft. long. Thus, the first job was to build elevated manholes at suitable points along the sewer. When this construction was completed cleaning operations were started. Several types of cleaning tools were tried, the best results being obtained with expanding cutters and a 20-in. brush. Frequent cleaning of the sewer prevented the overflow of waste to the stream and eliminated the polluted condition of the stream. However, cleaning operations were necessary every 3 weeks, and as the cleaning tools and equipment had to be lowered over retaining walls for placement in the manholes, the cleaning operation was difficult and expensive. In 1942, therefore, a new 30-in. intereceptor was constructed to replace the old 20-in. line. With suitable and ample manholes, this line only requires cleaning three times annually.

At the same time the lift station was modernized by installing a grit chamber and comminutor, by passing the sewage around the old receiving tank directly to the pumping station wet wells, and installing an additional 2,500-g.p.m. pump and an additional 16-in. force line from the pumping station to the settling tanks, a distance of 2,700 ft. These improvements provided an adequate intercepting sewer and adequate pump and force main capacity.

The increase in solids received at the settling tanks was very noticeable. Due to the fact that the solids were retained in the two primary tanks for as great a period as possible, the detention period grew less daily. Solids had to be removed from the primary tanks through bottom drains, the raw sludge being discharged to lagoons without underdrains or filter material of any kind. Inasmuch as the lagoons were at approximately the same elevation as the adjacent stream, seepage was slow and sludge drying was largely dependent on evaporation.

Due to the necessity of bypassing the secondary settling tank when drawing sludge from the primary tanks, a considerable quantity of solids was deposited periodically on the trickling filter bed. Over a 10-yr. period this practice caused a complete stoppage of the original filter bed, making it necessary to construct an additional filter of equal capacity during 1947. Present plans call for removing and cleaning the stone in the old filter and the construction of digesters.

Reduction of Tannery Wastes

The Ballston Spa plant of the American Hide and Leather Co. manufactures all of the side leather marketed by this corporation. In the process more than 100 different ingredients are used, the principal ones being lime and chromium. Hides are received at the tannery in the green state; that is, treated with salt and tied in bundles, the salt acting as a pickle. The salt must be removed and the hides dehaired, after which they are passed through the various stages of processing and finally through the tanning vats. After tanning, the hides are separated, making two sides per hide, these sides being then split to make two grades of leather. After the finish-

ing processes the hides are ready for use as shoe uppers and fine leather goods. The tannery wastes contain the salt removed from the hides, spent lime, and the residue from other treatment processes. The physical characteristics of the wastes vary greatly.

Originally, all hair removed from hides was discharged to the sewer. After investigation the industry installed, at great expense, a hair washing machine, dryer, and bailing attachment for handling all the long hair removed from hides. This action resulted in increased revenue for the industry.

A Dorr rotary screen (⅛-in. perforations) with elevators and a stack hopper was also installed at the tannery. All the plant wastes were passed through the screen before entering the village sewers, so that heavy hair ordinarily does not reach the sewage plant. However, the plant does receive practically all of the fine hair or fuzz from the hides, this material being almost impossible to remove by any screening operation. The fine hair and fuzz, however, together with the dissolved animal fats, causes increased deposition of solids in the intercepting sewer.

Treatment of Tannery Wastes

Installation of settling tanks at the tannery for pretreatment of the wastes has not been advocated. Experience at Ballston Spa has indicated that the tannery wastes can be handled at the municipal plant to greater advantage if received daily and not stored by the industry. This practice, however, requires careful operation control of the treatment units.

The Ballston Spa treatment plant is not equipped with a flow meter of any kind, the daily flow being estimated by calculation of the total sewage pumped to the plant. An ordinary recording pressure gage provides a continuous chart of the discharge-line pressure. From this chart the operating period of each pump, or combination of pumps, is readily determined.

Careful gaging has provided rather accurate discharge rating factors for each pump and combination of pumps. Thus, the length of time a pump operates multiplied by its discharge rating factor gives the volume of sewage pumped. The discharge rating factors for the pumps are determined annually.

It has been held by some that tannery wastes cannot be successfully digested. Nevertheless, plans have been made for the future installation of digesters at Ballston Spa. This action is based on experience gained from a pilot digester operated over a period of about 1 year, which proves conclusively that the solids received by this plant can be successfully digested. The resulting gas has a high carbon dioxide content that will be reduced by washing the gas with plant effluent (pH 11).

Lengthy tables of statistics concerning the character of the sewage have been purposely omitted, as the Ballston Spa sewage is vastly different from most others. A typical average sample of the sewage plant effluent would contain 2,998 p.p.m. total solids, of which 456 p.p.m. would be suspended solids and 160 p.p.m. settleable solids. The filter effluent B.O.D. averages 102 p.p.m. and the plant effluent 126 p.p.m. Stream samples ½ mile above the plant outfall indicate a D.O. and per cent saturation of 12.0 p.p.m. and 80.2 per cent, respectively, with the values ½ mile below the outlet being 13.8 p.p.m. and 90.4 per cent. No complaint is anticipated with these results.

Conclusions

Few sewage treatment plants can be completely rebuilt over a period of many years. In treating trade wastes at municipal sewage plants operators must keep pace with the constantly increasing industrial production and the resulting greater quantities of in-

dustrial waste. At Ballston Spa the production of the tannery tributary to the municipal sewage plant has increased 1,500 per cent in the past 20 years. When a production increase of this magnitude occurs at an industry using a wet process, its effect is transmitted directly to the sewage treatment plant receiving the waste. Such a condition will keep any operator busy, at least during the daily peak flow periods.

DISCUSSION BY W. R. SCHREINER *

In discussing the waste treatment problems at Ballston Spa, Mr. Porter has the advantage of three viewpoints. First, he spent 5 months in the winter of 1936–37 breaking in the newly remodeled plant as the supervising engineers' representative; secondly, he has operated the plant continuously since 1939; lastly, and most unusually, he is a long-time member and a past president of his local chapter of the Fish & Game Club.

This discussion of Mr. Porter's paper is from the standpoint of a district engineer of the New York State Department of Health. The department, in the years from 1933 to 1940, actively promoted the use of Federal grants in the remodeling of many outmoded sewage treatment plants. The allotment of P.W.A. funds to Ballston Spa in 1934 was one of the earliest fruits of such promotion.

The aim at Ballston Spa had been to put an end to the odors resulting from the continued emergency discharge of foul-smelling tannery liquors into Gordon Creek, right in the middle of the village. Therefore, a continuation of such discharge after the remodeling of the sewage plant was unthinkable. It was the writer's job to encourage the village board to hire properly qualified personnel, and, pending this, to see to it that the plant was operated in such fashion as to stop the outlet stream odors.

This program of encouragement began with the very first meeting of the newly elected village board in the spring of 1937. It continued until a fully qualified superintendent was appointed in 1939.

Tannery officials pointed out that the old 20-in. trunk line, located along Gordon Creek, would not carry the early flush of beam house wastes because it was either too small or was clogged. Village officials contended that it was impossible to keep the sewer clean because of the amount of clogging materials in the tannery waste liquors. These tannery wastes, discharged from 4 A.M. to 8 A.M., contained as much as 70 ml. per liter of settleable solids. They included all the long hair from the cattle hides, together with the fleshings, skinning debris, skin trimmings, and lime sludges. Not only would the trunk sewer line be clogged rapidly and completely, but it also required men with hay knives and pitchforks to remove the fresh sludge settling out in the equalizing reservoir sump at the pumping station. One or both lift station pumps would clog and the final settling tanks of the sewage plant would be jam-packed with a felt-like mass that could not be moved out to the drying beds. As long as the tannery liquor was allowed to spill over into the creek at the factory, all this trouble would be avoided.

The village officials were encouraged to the point of keeping the trunk lines clean. It required a crew of 3 men working 3 weeks to clean the trunk line with drags; in 2 days they would have to start in again. Everyone was amazed, however, to find that the 20-in. trunk line would carry the tannery wastes if it was clean, and if the 8 beam house vat plugs were pulled one

* District Engineer, New York State Department of Health, Glen Falls, New York.

at a time, instead of all at once. To help out, the tannery changed the dehairing process, installed hair shavers, and recovered the hair by means of washing, drying and bailing equipment that turned out a hair by-product of real commercial value. No longer was there fresh sludge at the pump station that had to be moved with a pitchfork.

This tannery improvement encouraged the village to put the cleaning of the trunk sewer line on a semi-emergency basis. Once the tannery officials became convinced that the village was going to be encouraged to keep the sewer line open, several of the writer's recommendations to the tannery were adopted. The old disc fine screen that hadn't been used for years was junked, and an adequate drum-type fine screen was installed to take out the skin trimmings and fleshings, which had been clogging the pump impellers. This change encouraged the village to put the trunk line dragging on a semi-routine basis.

It was then found that the interceptor could be dragged in 10 afternoons, and that the cleaning would be good for another 2 to 4 weeks, except during rainy spells. For some reason, 5 days after a heavy surface runoff and high water in the creek above the trunk line, there would be signs of loss of sewer capacity and the tannery workmen would start removing the clamped-down cover of the emergency discharge manhole. It was not until Mr. Porter came back as superintendent and introduced engineering methods to the sewer cleaning task that the effect of sewer growths was discovered.

The clogging effect of zoogloeal growths had been noted by the writer in sewers in Westchester, where considerable quantities of ground water gained entrance. There, a sewer line serving five houses had to be dragged once a month in the spring and in the late fall to remove the voluminous growths. Mr. Porter found that these long sewage fungus streamers attached to the high-water grease line in the upper third of the sewer arch and increased enormously in length when bathed in street run-off and creek infiltration. They retarded even the low flows and thus hastened the deposition of lime sludge and fleshings deposits. Following the discovery of the type and extent of the sewer growths, it was easy for the village officials to understand that any replacement of the old 20-in. sewer should not be laid along the stream bank, but should be located in the streets.

The voluminous tannery sludges caused, and still cause, many modifications in plant operation. Several of the unsolved operation problems are: (1) the handling of large volumes of high pH sludge, especially when the sludge is fresh and so sticky; (2) the oxidation of the settled sewage without clogging the trickling filter; (3) the transfer of sludge from the settling tanks to the digesters; (4) the rate and degree of sludge digestion; and (5) the disposal of digested sludge.

There is so much nitrogenous material in the sewage that the air around the treatment plant is surcharged with ammoniacal vapors. It is impossible to prepare ammonia-free water in the plant laboratory and impossible to prepare or keep Nessler's solution. Perhaps it would be advisable to add hammer-milled garbage to the digesters. This would solve the garbage disposal problem, also acute at Ballston Spa. It would make up for the present deficiency of fermentable carbonaceous matter in the sewage solids. Such an addition might markedly shorten the liquifying time of the cycle of nitrogen degradation necessary to successful sludge drying procedures.

One of Mr. Porter's accomplishments deserves special mention. Instead of pining away for lack of a flow meter, he uses the daily charts from the recording pressure gauge on the lift station force main to compute the daily

flow and to make reasonable estimates of rates of flow for critical periods. The method is simple, trustworthy, and exceedingly useful in a variety of ways. It is recommended for the consideration of every operator and every consulting engineer.

I should say a few words about the receiving stream, Kayaderosseras Creek. When the tannery wastes were being discharged directly to the Kayaderosseras, sludge banks were observable for 2 to 3 miles below the tannery. With the wastes being discharged to the Ballston Spa sewage treatment plant for the last 9 years, the sludge banks have disappeared. Although the plant effluent has more than 2,000 p.p.m. of dissolved solids, and during the low summer flows the dilution is no more than 8 to 1, the stream recovers quite satisfactorily in the 10-mile run to Saratoga Lake. In fact, several residents along the lower reaches of the stream use the creek water for general household purposes, and one family is known to use the river water for drinking during the spring and fall.

TIPS AND QUIPS

Multiple Dosing of Sludge Beds

What would be your reaction if some one suggested that no sludge be removed from the beds during the summer, but that instead it be built up in 2, 3, 4, or more layers and, therefore, only removed once a year—in the early spring? Would you surmise such a procedure would result in less sludge drying per unit of area, or would you merely wonder what the results would be?

Multiple dosing was tried during 1948 on one sludge bed at the Fort Wayne, Ind., sewage treatment plant. Results were that 12.1 lb. of sludge were dried per square foot of sand area, whereas for the rest of the sludge beds the average was 13.0 lb. per sq. ft. The loss in sludge drying capacity is about 7 per cent, but Superintendent Ralph A. Hoot says that this method would have the following advantages:

1. Considerable sludge labor could be saved to be devoted to other plant work. This would come about because in Fort Wayne much of the early spring sludge is removed directly from the beds by Fort Wayne citizens, whereas during the rest of the year sludge is removed by the plant sludge crew. By "storing" the year's supply of sludge on the beds, users would do most of the removal labor.

2. In early spring the sludge, after alternate freezing and drying during the winter, is fine and granular; during warm weather the sludge bakes into lumps greatly resembling coke. Hence, by the repeated loading method there would be obtained a finer type sludge more readily acceptable to po-

FIGURE 1.—Multiple-dosed sludge bed at Fort Wayne.

tential users, thus increasing the demand and reducing the quantity to be otherwise disposed of.

The sludge bed used for the Fort Wayne experiment has 8,450 sq. ft. of sand area; the area of the remaining beds is 226,000 sq. ft. The one bed was loaded 7 times. The other 11 beds were loaded and unloaded 44 times, or an average of 4 times each. Figure 1 shows the test bed with one runway cleaned and sludge 6½ in. deep on the level.

Hand Tailored Filter Stone

Filter stone can be a costly item, even with the mass production methods used today. One plant, however, enjoys the distinction of having its filter medium entirely hand made!

When new filters were to be installed at the plant of the Southern Michigan State Prison at Jackson, the cost for stone seemed too high to one alert party. Thinking of the hands that needed work to keep them out of mischief, he decided to utilize some of the potential energy stored in the adjacent "pen."

Plenty of rock was available, but all too large. Also, some was too soft and friable to make good filter material. Simple tests, however, showed that the process of "making little ones out of big ones" could also serve the purpose of eliminating the poor stone. Thus, if a rock broke with one or two hammer blows it was discarded as too soft.

The "crushed" stone was sized by hand as produced, and then placed in what are probably the only filter beds in America containing hand tailored stone.

Use with Caution

Control of flies in percolating filters by means of DDT and Gammexane seemingly offers an easy way out for the harassed operator. However, indiscriminate dosing with the modern insecticides can lead to headaches just as bad as those occasioned by the flies, as shown by the results of experimental work reported in the recently issued annual report of the British Water Pollution Research Laboratory.

In general, the report carries the implied warning that even low dosages may result in effluents toxic to fish and other water life. Therefore, the insecticides must be used in carefully measured amounts.

The lowest effluent concentration of DDT used was 0.005 p.p.m., which was distinctly toxic to the fish used in the experiments. Liquids containing the corresponding concentration of solvents and emulsifying agents, but no DDT, were not toxic. If present, however, in concentrations equivalent to those in an emulsion giving 0.4 p.p.m of DDT in the effluent, toxicity began to be evident. Thus, the toxicity was due mainly to DDT, although the emulsifying agents and solvents were toxic if present in sufficiently high concentration.

The experiments showed that, in general, fish exposed to even small concentrations of DDT for more than just a few minutes subsequently died. Effluents from filters treated with DDT in a concentration of 10 lb. per acre were toxic; with 20 lb. per acre, markedly toxic. Effluents from filters treated with as little as 1 lb. per acre of Gammexane were toxic.

Fly control was generally more effective with monthly treatment of relatively clear and lightly loaded filters. Poor results were obtained during the early treatments on heavily loaded filters containing large amounts of biological film, although continued treatment gave better results. Indications are that more frequent applications of insecticide—perhaps weekly or biweekly, instead of monthly—would give better results on the latter class of filters.

Close Surveillance

That at least one plant superintendent has more than his heart and soul in his work is attested by an item in the log of "Highlights of the Year" contained in the 1948 annual report of the Belvidere, Ill., sewage treatment department. The entry reads:

"Supt. lost eyeglasses in aeration tank—removed after one hour's work using rake—no damage to glasses."

Could this be the first phase of an experiment in remote control observation of bacterial life in activated sludge?

Safety (?) Devices

"It was found that the gas control equipment was not functioning properly." With this innocent appearing statement R. D. Craun, superintendent of the Rochester, Mich., sewage treatment plant, in his annual report for 1946, begins a recital of some of the things he found on taking over the plant.

Expanding on the statement, Mr. Craun goes on to say that the erratic performance of the gas controls led to inquiries which elicited the information that about a month before an accumulation of scum between the digester sidewall and the cover skirt had held the floating cover suspended while supernatant was being drawn. Several feet of liquid had been withdrawn before the cover released and suddenly dropped the entire distance.

It was obvious that the sudden pressure surge had probably damaged all of the diaphragm-regulated equipment, so careful examinations were made. The vacuum-pressure relief assembly mounted on the digester cover was found to have the fill-pipe, the seal-liquid reservoir, and the flame-trap assembly filled with a thick scum; the diaphragm was cracked and very brittle. The diaphragms of the other controls were ruptured, perforated, or stretched, so that a general replacement was made. It was also discovered that a nail had been used to replace the fusible link in the thermal plug of the Varec flame-trap assembly.

Further examination revealed that the automatic safety valve, which is controlled by the boiler hot water limit control or the pilot flame through the thermocouple lead, was so deteriorated as to be unrepairable. This was replaced by another of a newer, more efficient type.

Obviously, safety devices are only dependable to the extent that they are kept in good operating condition by inspection and maintenance. Corrosion or other deterioration is bad enough, but when the very link on which the whole device depends is short circuited or replaced by jumpers, nails, pennies, and the like, the way is opened for disaster. In this case, we're happy to be dutifully passing on a reminder to other operators, rather than abstracting an accident report that begins "Because of a nail. . . ."

Water Hammer Arrester

Water hammer is a very common hydraulic phenomenon encountered whenever water in motion is suddenly stopped. Spring operated and check valves almost always cause water hammer, the effects of which may be felt hundreds of feet from the source. The sudden surges of pressure often exceed 800 lb. per sq. in. and are a major cause of pump damage, equipment failure, and even pipe rupture.

To combat the damaging effects of water hammer, many installations use capped pipe air chambers. Such air spaces soon become water-logged and inoperative, and even when provided with valves or petcocks to permit drainage they require regular, frequent service, increasing maintenance costs without reducing equipment hazard.

A new device on the market provides an air cushion to absorb the water hammer pressure impulse, but positively prevents water logging of the air chamber. An ingeniously fabricated metal bellows (Figure 2) allows

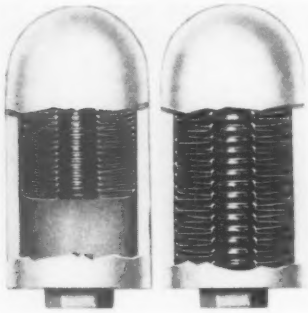


FIGURE 2.—Water hammer arresting device absorbs shock by compression and decompression of air sealed within bellows.

free contraction and expansion of the air sealed within it, but prevents all contact between air and water. Thus, the air chamber is continuously effective and provides constant protection against water hammer. Advantages claimed for the water hammer arrestor include ease of installation and elimination of all maintenance or servicing needs thereafter.

Lower Away!

As welcome as the flowers in spring is the news that general selling prices on cast iron pipe and fittings have been reduced $11 per net ton by the U. S. Pipe and Foundry Company, of Burlington, N. J. Of this total reduction, $4 is occasioned by a decline in pig iron prices, effective May 1, and follows a reduction in general selling prices of $7 per net ton announced by the company on April 25, prior to the pig iron price decline.

Looks as though some of that feeling of frustration will be relieved now that maintenance and replacements ease off on the budget a little.

Dream Comes True

Glass-covered sludge drying beds or sedimentation basins of sewage treatment plants have many times been mistaken for "greenhouses" by ill-informed individuals. At DeKalb, Ill., however, a long time dream of Superintendent D. E. Henn has finally come true in the form of a real greenhouse for plants and seedlings.

Beautification of the grounds at the plant has been a policy of the DeKalb Sanitary District for some years. In fact, the beautification policy has extended to the entire community, with flower plants and bulbs grown at the treatment plant being distributed to local horticulturists. In 1948 over 2,000 aster plants were raised, of which 1,000 were set out on the plant grounds and the remainder given away. Over 1,700 gladiolus bulbs were planted and produced many beautiful blooms of 25 named varieties. Of the more than 3,000 bulblets planted, many grew into blooming size bulbs for the 1949 season.

With such a gardening program it has become increasingly difficult to carry over plants during the winter and provide space for starting seedlings. The office simply wasn't big enough to be both an office and a hothouse! By March, 1948, however, the public relations value of the beautification program had so impressed the District's Board of Trustees that a small greenhouse—15 ft. by 17 ft.—was authorized. The structure, assembled during the summer by plant personnel, is heated by hot water from the gas fired boiler located in the office. Therefore, the cost of operation should be practically nothing.

And the public relations value should be infinitely great!

Heat for the Cold Spots

Chlorinator troubles last winter led Lester Pope, operator of the Hamilton Township, N. J., sewage treatment

plant to look for help from—of all places—the local gas company. True to its name, the Public Service Gas Company performed a truly public service.

The trouble had been found to be not with the machine, but with the chlorine itself, due to low building temperatures. On a good cold morning the temperature in the chlorine building, a separate building heated by a 2-burner oil stove, might be as low as 40. As the sun came up it might go up to 55; on a warm day, as high as 80. The variation, of course, interfered with proper control of chlorine dosing.

Service personnel from the gas company, when informed that a constant temperature was desired and that sewage gas was to be used, recommended a unit heater equipped to burn digester gas. The heater installed is a unit hot air heater suspended from the ceiling. A thermostat near the chlorinator controls the electric fan, which in turn has a fly-ball governor controlling the main burner.

This makes the perfect outfit, as the chlorine building is kept within 2 degrees of the thermostat setting. In addition, the installation has pointed the way to an easy and economical method of heating out-of-the-way buildings or spaces in any part of a plant with only the cost of using the excess digester gas supply.

Better Brush Control

The newest thing in chemical weed and brush control is reported to be 2, 4, 5-T. Using the stuff should be easier than trying to call it by its proper name, however, for as the chemists say it this new weed killer is the "isopropyl ester of 2, 4, 5-T trichlorophenoxyacetic acid." It is a close cousin of the well-known 2, 4-D, and similarly kills by hormone action.

2, 4, 5-T, is a welcome addition to chemical hormone weed killers, as it is purported to give better control than 2, 4-D of poison ivy, poison oak, and brambles, as well as willows and many other woody perennials. Users can look forward to more effective control of hard-to-kill brush plants where they are a problem in fence rows, ditch banks, rights-of-way, etc. Commercial weed killers based on the compound are said to mix readily with water or oils and to be useable in combinations with 2, 4-D for extended coverage and utility. The best time to use preparations of 2, 4, 5-T is during spring and early summer when plants are growing rapidly and the leaves are fully developed.

Match This One!

As any operator knows, every so often his plant is called on to handle untreatable material, sometimes without his previous knowledge. The general public is all too prone to "dump it down the sewers." One instance that has come to our attention, however, bypassed the sewers and struck right at the heart of the treatment plant.

A newspaper account of vandalism last Halloween in Williamsville, Ill., after noting that every fire hydrant in the village had been opened, thus reducing the fire-fighting potential to the vanishing point, goes on to say:

> "The gang, apparently led by adults, then ripped up an entire barbed wire fence, snarled the wire about the wooden posts, and dumped the bundle into the disposal plant. Workman labored for several hours to remove it so that normal disposal procedure could be resumed."

Anybody know the B.O.D. and pH of barbed wire?

Editorial

TREND TOWARD PREAERATION

A recent survey of sewage treatment design practices has directed our attention to a trend that has been gaining force more rapidly than may generally be realized, i.e., the increasing employment of preaeration or "air-flocculation" in new and existing plants. This takes us somewhat by surprise—not because preaeration is lacking in its promised advantages, but because such trends are usually prefaced by a prolific technical literature on the results of fundamental research and operating experience. In this case the logically anticipated benefits of preaeration seem to have sold the practice without full evaluation of its capacities and limits.

Possibly the first plant scale preaeration installation in the U. S. is that at Decatur, Ill. (THIS JOURNAL, **3**, 4, 621; October, 1931), which was built in 1928. Although early studies showed substantial benefits from plain aeration alone, the Decatur facilities have been applied most of the time for short-period activated sludge treatment. Preaeration is not even mentioned in the functional outline of sewage treatment processes contained in Chapter II of the Federation's Tenth Anniversary Book "Modern Sewage Disposal," indicating that the practice was hardly recognized as a conventional one at that time (1938). The 1945 sewage treatment inventory compiled by the USPHS Water and Sewage Investigations Station lists only 28 air-flocculation installations, although this number is believed to be low because several known installations are not so indicated in the census. Preaeration therefore, may be classed as a "new development," and its current popularity as reported by state sanitary engineers merits notice.

Also noteworthy in connection with this development pattern is the fact that the present trend is not supported by the exploitation and sales pressure which accompanies the promotion of patented processes. The writer is not aware of any process patent involvement in preaeration applications, although some arrangements of flocculation chambers in sedimentation tanks are proprietary.

In the January, 1948 issue of THIS JOURNAL (page 115), Walker submits a highly enthusiastic case in favor of preaeration as a means of improving the "treatability" of sewage, and urges study of the efficacy of operating installations. We heartily endorse his plea for such investigations, and will welcome the opportunity to publish conclusive data and other findings.

Among the apparent returns from preaeration are:

1. Flocculation of fine suspended matter and colloids, with greater efficiency of solids and B.O.D. removal by primary sedimentation.
2. "Scrubbing" out and dilution of entrained gases capable of creating odor nuisance.
3. Freshening or "conditioning" of the raw sewage, with related improvement of general conditions during subsequent treatment.
4. De-emulsification and flotation of grease (and, possibly, greater removal of grease with settled solids).
5. Mixing and dispersion of small batch discharges of toxic or otherwise objectionable industrial wastes.

6. Induced precipitation and coagulation in the presence of certain chemical salts.

7. Nominal direct B.O.D. satisfaction.

Some of these advantages would be realized by mechanical flocculation without air; others would not.

It occurs to the writer that air-flocculation might also be employed advantageously ahead of sedimentation tanks receiving trickling filter (especially high-rate) effluents. So used it would be expected to supplement and complete the bioflocculation effected in the filters, affording higher over-all efficiencies.

Walker, in the discussion cited above, defines preaeration as being complete only when sufficient oxygen has been added to the sewage to supply a 0.2 p.p.m. D.O. content after 60 minutes storage in a stoppered bottle. He goes on to say that 10 minutes or as much as 10 hours of preaeration may be required to reach this threshold. Certainly the economies of any installation providing more than one hour of preaeration would be doubtful in most cases, for the reasonable expectancy in flocculation, flotation, freshening, and release of entrained gases should be achieved in an hour or less.

It would appear logical that the benefits accruing from preaeration would be largely dependent upon the strength of the raw sewage and the nature of industrial wastes present therein. Little or no advantage would be expected where the sewage is fresh, dilute, and of domestic origin; startling values might be found in the treatment of strong, stale, and variable industrial sewages, particularly where there may be substances that would coagulate during preaeration. But where is the limit above which preaeration will pay its way? What types of industrial wastes are most likely to submit to the process? Under what conditions might it be feasible to resort to extended preaeration in the interests of over-all plant economy and operating efficiency?

There are already enough operating preaeration installations to supply much of the basic information that would be useful. At some of these plants the layouts will permit comparative studies that would be especially interesting and valuable. Data made available up to this time have been regrettably meager, and it is hoped that those who are in a position to furnish information will meet the need.

Considerable fundamental research applicable here has been conducted in connection with studies of the activated sludge process, grease removal, and mechanical flocculation. This work could be reviewed and supplemented with profit.

It has often been the case in the past that considerable misapplication has resulted when a sewage treatment process or device has struck a "run" of popularity. It is not the purpose of this discussion to discourage preaeration installations, but rather to encourage their use when, where, and as they will serve best. Wise use of this or any other tool is attainable only when its mechanics are understood, its capacities and limitations known, and its costs balanced against benefits.

W. H. W.

Proceedings of Member Associations

ARKANSAS WATER AND SEWAGE CONFERENCE

Eighteenth Annual Meeting

Little Rock, Arkansas, April 11–13, 1949

The 1949 Annual Meeting of the Arkansas Sewage Works Section was held during the Eighteenth Annual Arkansas Water and Sewage Conference and Short School. The meeting was held in cooperation with the University of Arkansas and the State Board of Health. Sessions were held in the Municipal Auditorium, with headquarters at the Marion Hotel.

Mayor Sam Wassell, Little Rock, in the opening address of the meeting, extended the city's welcome to the Conference members. Following Chairman Solon Sanderson's response, a moving picture, "Clean Waters" was shown.

A valuable series of technical sessions were held at the meeting under the general topics of water purification, meters, distribution systems, and distribution and sewage.

At the business meeting of the Sewage Works Section, action was taken to amend the constitution to provide for the increase in Federation dues, effective January 1, 1950, the date SEWAGE WORKS JOURNAL begins monthly publication. The Section expressed its unanimous approval of the monthly publication of SEWAGE WORKS JOURNAL.

Frederick L. McDonald, Chief Sanitary Engineer of the Arkansas State Board of Health, was nominated for the FSWA Arthur S. Bedell Award for outstanding services rendered. The presentation will be made at the Annual Meeting of the Federation in Boston, October 18–21.

Elected to succeed F. L. McDonald as FSWA Director was Ben W. Dees of Little Rock. Mr. Dees's three-year term will begin October, 1949.

HARRISON HALE,
Secretary

OKLAHOMA WATER AND SEWAGE CONFERENCE

1949 Meeting

Oklahoma A. & M. College, Stillwater, Okla., January 24–27, 1949

The Oklahoma Water and Sewage Conference held its Twenty-second Annual Water and Sewage Short Course at the Oklahoma A. & M. College, Stillwater, January 24–27, 1949. A total of 110 members and guests participated in this year's program with renewed interest.

The technical program consisted of lectures and panel discussions, which were supplemented by laboratory sessions. Topics covered in the sewage works program were sewage characteristics, sewer maintenance, treatment of sewage, sludge digestion, and pumps and sewage lift stations.

Professor Earnest Boyce presented the subject, "Relationship of Health Departments to Water and Sewage Works Personnel," at one of the evening sessions. Also on the evening program was Frank S. Taylor, FSWA Director, who gave a report on the Federation.

As in the past, the outstanding event of the Conference was the annual dinner meeting, held Wednesday evening, January 26, 1949. The guest speaker was Colonel Jack J. Hinman, Jr., U. S. Army Engineers, retired, Iowa City, Iowa. Colonel Hinman spoke with interest regarding the water supplies in Japan. Following the presentation of awards, the business meeting and election of officers was held.

The Conference adopted the increase in dues to the Federation of Sewage Works Associations, effective January 1, 1950, and its constitution was amended to cover the action taken.

Officers elected for the year 1949 are as follows:

President: Curtis E. Moutrey, Tulsa.
Vice-President: Grover L. Morris, Oklahoma City.
Secretary-Treasurer: H. J. Darcey, Oklahoma City.
FSWA Director: Frank Taylor, Oklahoma City.

H. J. DARCEY,
Secretary-Treasurer

KANSAS SEWAGE WORKS ASSOCIATION

Fourth Annual Meeting

Hutchinson, Kansas, April 21–22, 1949

One of the major highlights of the Fourth Annual Joint Meeting of the Kansas Sewage Works Association and the Kansas Section, American Water Works Association, was an address by the Honorable Frank Carlson, Governor of Kansas. In his discourse on the responsibilities of the water and sewage works professions, Governor Carlson expressed satisfaction at the keen desire for knowledge he had observed at the meeting. The meeting, held on April 21 and 22, 1949, at the Hotel Bisonte, Hutchinson, Kansas, is believed to be the first annual meeting of a member association of the Federation at which the Governor of a state has been a speaker.

The morning session on April 21 included papers on the Hutchinson water system and emergency maintenance, in addition to the following: "Report of (Kansas) Legislation Authorizing Sewer Service Charges," by C. M. Williams, commissioner of streets and sewers, Topeka.

"The Water Pollution Control Program of the U. S. Public Health Service," by Glen Hopkins, U.S.P.H.S. officer in charge, Missouri River Basin, Kansas City, Mo.

The afternoon session was devoted almost entirely to water utility problems. C. Hagar, secretary of the Kansas Section, A.W.W.A., reported on pending state legislation providing retirement for state and municipal employees.

After a buffet supper, business meetings of both the Kansas Sewage Works Association and the Kansas Section, A.W.W.A., were followed by delightful entertainment and the awarding of door prizes.

With the exception of a paper on geologic methods of prospecting for ground water, the entire morning session on April 22 was devoted to panel discussions of sewage plant problems. Under the leadership of L. T. Hagadorn, consulting engineer, Salina, the respective members of the panel cov-

ered the following subjects: "Operation of an Activated Sludge Plant," Ray Conant, superintendent, Herington; "Maintenance of Trickling Filters and Separate Sludge Digesters," Roy Binder, superintendent, Hays; "Operation of an Incinerator as Part of a Sewage Treatment Plant," Lloyd Hankins, superintendent, Winfield; "Maintenance of Imhoff Tanks," C. M. Cooper, city engineer, Pittsburg, Kans. This was followed by an "Operators' Forum," presided over by Ben Lee, superintendent at Hutchinson.

The afternoon session on April 22 was devoted to "clinics" and panel discussions on waterworks maintenance problems. In the evening more than 150 enjoyed the annual banquet, at which the annual awards were presented.

Total registration at the meeting was 190, of whom 22 were ladies; 18 members of the Kansas Sewage Works Association attended.

At the business meeting the following officers were elected for the coming year:

Chairman: Roy Binder, Hays.
Vice-Chairman: D. B. Kissinger, Topeka.
Secretary-Treasurer: Dwight F. Metzler, Lawrence.

Dwight F. Metzler,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Pennsylvania Sewage Works Association	Nittany Lion Inn, State College, Pa.	Aug. 24–26, 1949
Iowa Sewage Works Association	Hotel Kirkwood, Des Moines, Ia.	Sept. 20–22, 1949
Rocky Mountain Sewage Works Association	Acacia Hotel, Colorado Springs, Colo.	Sept. 21, 1949
Georgia Water and Sewage Works Association	Georgia Institute of Technology Atlanta, Ga.	Sept. 21–23, 1949
West Virginia Industrial Wastes and Sewage Works Association	Ogleby Park, Wheeling, W. Va.	Sept. 21–23, 1949
Canadian Institute on Sewage and Sanitation	McIntyre Arena, Schumacher, Ontario, Canada	Sept. 26–28, 1949
South Dakota Sewage and Water Works Conference	Alex Johnson Hotel, Rapid City, S. Dak.	Sept. 28–30, 1949
Federation of Sewage Works Associations	**Hotel Statler, Boston, Mass.**	**Oct. 17–20, 1949**
New England Sewage Works Association	Hotel Statler, Boston, Mass.	Oct. 17–20, 1949
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Lafayette and Phoenix Hotels, Lexington, Ky.	Oct. 31–Nov. 2, 1949
North Carolina Sewage Works Association	Highland Pines Inn, Southern Pines, N. C.	Nov. 7–9, 1949

Federation Affairs

BOSTON CONVENTION DEVELOPMENTS

Early indications are that the Twenty-second Annual Meeting of the Federation of Sewage Works Associations, to be held at the Hotel Statler, Boston, Mass., on October 17–20, 1949, will be the most significant pollution abatement conference in New England since Boston Harbor received its initial world-shaking overload of tea "wastes" in 1773. The New England Sewage Works Association is acting as host in the historic "Hub" city.

The membership of the Local Arrangements Committee, which has already completed many of the final details, comprises the following subcommittee chairman:

General Chairman: E. Sherman Chase, consulting engineer, Boston.
Hotel Arrangements: Edwin B. Cobb, consulting engineer, Boston.
Registration: Jack E. McKee, consulting engineer, Boston.
Finance: Thomas A. Berrigan, director and chief engineer, sewage division, Metropolitan District Commission, Boston.
Transportation: Ralph W. Horne, consulting engineer, Boston.
Inspection: Robert W. Moir, Metropolitan District Commission, Boston.
Local Host: Charles G. Hammann, public health engineer, Blackstone Valley Sewer District Commission, Providence, R. I.
Entertainment: Clair N. Sawyer, associate professor of sanitary chemistry, Massachusetts Institute of Technology, Cambridge.
Ladies' Entertainment: Mrs. Thomas A. Berrigan.

Hotel Accommodations

Those planning to attend the meeting are urged to make hotel reservations without delay, as Boston is a very active convention and tourist city during the fall months. Requests for reservations should be directed to the Hotel Statler, which will be headquarters for all technical and social events of the meeting.

Technical Program

Topical coverage of the technical program is unusually comprehensive, with major emphasis divided between stream pollution, sewage treatment, and industrial wastes treatment. Among the program innovations is a full session devoted to an "Industrial Wastes Forum." This attraction, which should prove especially interesting to those concerned with this phase of pollution control, will be presided over by Stuart E. Coburn, chief chemist of Metcalf and Eddy. It will run concurrently during the Thursday morning session with the always highlighted "Operators' Forum," presided over by LeRoy W. Van Kleeck, principal sanitary engineer, State Department of Health, Hartford, Conn.

The Monday afternoon symposium on industrial wastes, received with such acclaim in recent years, will this year feature several outstanding papers on treatment of wastes currently receiving much attention by operators, researchers, and regulatory bodies.

Of general interest will be papers on the results of comparative tests and studies of air diffusion for activated

sludge, on bacterial standards for natural waters, on training of sewage works operators, and on progress results in the Federation-sponsored experimental research on analytical methods, as well as a discussion of mechanical equipment in sewage treatment. In addition, up-to-the-minute accounts will be given of the progress in solving both the sewerage and treatment problems of Metropolitan Boston. A full afternoon will be devoted to an inspection trip to the new Nut Island sewage treatment plant and its appurtenant collection structures. Special inspection trips are also being planned to noteworthy industrial waste treatment installations in and around Boston and nearby cities.

The feature of the Annual Federation Luncheon will be an address by Dean Gordon M. Fair, of the Graduate School of Engineering, Harvard University. Always an entertaining and forceful speaker, Dean Fair will discuss the place of the science of sanitary engineering in the changing world.

Social Program

Details of the social events of the convention are still in process of development. Included will be a Reception-Entertainment on Monday evening, October 17, and the Annual Dinner and Dance on Wednesday evening, October 19. A full schedule of special events for the ladies includes, besides ample shopping time, a "get-acquainted" tea, a tour of historic Boston and Charlestown, and a trip through the history-rich area around Cambridge, Lexington, and Concord, with luncheon at the world-famous Wayside Inn at South Sudbury. The New England Sewage Works Association will hold its annual business meeting at a Wednesday luncheon.

Manufacturers Exhibit

Member companies of the Water and Sewage Works Manufacturers Association have indicated advance booking of all available exhibit space. Full occupation of the exhibit area by an interesting and diversified showing of equipment is thus assured.

Further Details Later

All Active and Corporate members of the constituent associations of the Federation will be sent a formal announcement of the convention in August. Further details for those planning to attend will be contained in that notice.

In the meantime, hotel reservations may be placed directly with the Hotel Statler, making mention that the accommodations are sought for the Federation convention.

PAST PRESIDENT FRIEL HONORED

On June 20, 1949, the honorary degree of Doctor of Engineering was conferred on Francis S. Friel, past president of the Federation, by Drexel Institute of Technology, Philadelphia, Pa. The recognition was awarded for "notable contributions to the health and prosperity of our people through his skill in sanitary technology, and to the security and well being of our country through his public services in both peace and war."

Mr. Friel is a member of many professional engineering societies, particularly in the field of sanitary technology and public health. He is a past president of the Pennsylvania Sewage Works Association, a recipient of the Kenneth Allen Award, and has served the Federation as director (1944–46), vice-president (1945–46), and president (1946–47).

Reviews and Abstracts*

Report of the Water Pollution Research Board for the Year 1947. Water Pollution Research Board (Great Britain). 52 pp. (1949).

Water

The effect of chlorine on corrosion of metals by water was investigated. No definite conclusions were drawn, although in some cases brass ball valves were corroded. The re-use of sea water for cleansing shell fish (mussels) was studied with artificial sea water, using 1 to 3 p.p.m. of chlorine. Apparently, doses of 1 p.p.m. or more of chlorine acting for 30 min. or longer destroyed nearly all coliform bacteria.

Sewage

At Minworth Sewage Works of the Birmingham, Tame and Rea District Drainage Board, alternating double filtration has been tested since 1938. In recent experiments on two filters at the rate of 150 g.p.d. (Imp.) per cu. yd. of medium, the doses of settled sewage applied, in g.p.d. (Imp.) per cu. yd., were:

Time	Sept. 1, 1946 to Aug. 15, 1947	Aug. 27 to Nov. 30, 1947
6 A.M. to 2 P.M.	75	71
2 P.M. to 10 P.M.	225	223
10 P.M. to 6 A.M.	150	161
Average	150	152

The 5-day B.O.D. of the settled sewage ranged from 126 to 185 p.p.m. The primary filter effluent B.O.D. ranged from 11 to 46 p.p.m. The secondary filter effluent ranged from 9 to 22 p.p.m., and contained from 14 to 28 p.p.m. of ammonia as N and 11 to 20 p.p.m. nitrite plus nitrate.

With filtration and recirculation of effluent in the same months, the final effluent was not quite so good as from the alternating double filtration plant.

The rate of treatment, in g.p.d. (Imp.) per cu. yd., was:

Time	Settled Sewage	Recirculated Effluent
6 A.M. to 2 P.M.	75	225
2 P.M. to 10 P.M.	225	75
10 P.M. to 6 A.M.	150	150

With bio-flocculation effluent treated on biological filters at the maximum rate of 150 g.p.d. (Imp.) per cu. yd., the final effluent was not as good as either the alternating double filtration or by filtration with recirculation of effluent.

Experiments at Coventry were conducted with single filtration (average 60 g.p.d. (Imp.) per cu. yd.); filtration with recirculation of effluent (average settled sewage 120 g.p.d. (Imp.) per cu. yd., recirculated effluent 120 g.p.d. (Imp.) per cu. yd.); alternating double filtration (average g.p.d. (Imp.) per cu. yd.). None of the effluents was of consistently good quality; many samples had a B.O.D. exceeding 30 p.p.m. The various effluents had a content of ammonia as N ranging from 20 to 34 p.p.m., and nitrite plus nitrate as N from 14 to 27 p.p.m. Some ponding and fungus growth appeared on all but the single filtration unit.

Sand filtration of biological filter effluent was tested in glass tubes and pressure filters equipped for backwash, using sand or finely crushed anthracite. The resulting effluent contained less than 10 p.p.m. suspended solids. The B.O.D. was reduced from 50 to 70 per cent.

Earlier experiments in 1946 showed that filter flies could be controlled for about 4 weeks by adding to influent sewage 1 lb.

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

of Gammexane or about 50 lb. of DDT per acre of filter. Further tests at 13 works, using 1 lb. of Gammexane or 10 lb. of DDT per month, indicated varying results, depending on the condition of the filters.

Effluents from filters treated with DDT were found to be toxic with 10 lb. per acre, and markedly toxic with 20 lb. per acre, or over. The lowest concentration of DDT used was 0.005 p.p.m., which was found to be distinctly toxic to trout, the toxicity being due mainly to the DDT itself. Results with Gammexane were inconclusive, although some fish were overturned where 1 lb. per acre was applied.

Industrial waste waters from processing of sisal and coffee in East Africa were examined. Sisal wastes have a pH around 5 and are 4 to 6 times as polluting as domestic sewage (by B.O.D. test). 3-day B.O.D. tests (at 26.7° C.) range from 610 to 4,850 p.p.m. Suspended solids range from 150 to 700 p.p.m. Coagulation with calcium hydroxide and ferric chloride was not considered suitable. Storage for 12 days was considered impractical. Percolating filters dosed with diluted waste are being tested. Re-use of waste waters may afford a saving of 80 per cent in water consumption.

Coffee wastes originate from pulping the cherries to extract the bean and from washing of fermented beans. From the first source, wastes may range from 1,440 to 3,890 p.p.m. 3-day B.O.D. at 26.7°C.; from the second, from 420 to 2,830 p.p.m. 3-day B.O.D. at 26.7° C. Suspended solids are also high (first type 390 to 440 p.p.m.; second, 250 to 3,260 p.p.m.).

Treatment of diluted wastes on biological filters is being studied. So far, results indicate that possibly 1,000 cu. yd. of filter stone are required per ton of coffee.

Operation of two milk washing treatment plants was examined. At one, condenser water goes direct to a river. The hot wastes are treated with hot alumino ferric (300 p.p.m.) solution and hot soda ash solution to raise pH to 7, allowed to settle overnight, and applied to a trickling filter 16 ft. deep. The effluent contained 14 p.p.m. 5-day B.O.D.

Waste waters from cider making have caused trouble, containing over 1,000 p.p.m. B.O.D. and pH 5 to 7. Treatment on trickling filters was helpful, handling diluted cider wastes mixed with domestic dewage.

Slaughter house wastes on a small scale are noted. Brief discussion is given on wastes from manufacture of dyestuffs and dyeing and finishing of textiles. The latter wastes were applied to biological filters with encouraging results.

Waste waters containing cyanides are discussed from a laboratory standpoint. The use of suitable absorbers was indicated, followed by iron solution to form ferrous ferrocyanide.

Toxicity of chlorinated sewage effluents is briefly discussed, where gas liquor is present and cyanogen chloride is formed. The smallest concentration of cyanogen chloride that is toxic to rainbow trout is about 0.08 p.p.m.

LANGDON PEARSE

Headaches from Treatment of Combined Industrial Wastes and Sewage. BY STUART E. COBURN. *Journal, Boston Society of Civil Engineers*, **36**, 64 (January, 1949).

The author discusses the effect of various wastes on sewage treatment, and, in particular, the effect of high temperature, dye wastes, and soluble oils which pass through a plant. Gasoline and mineral acids should be excluded from sewers. He lists the following as a source of trouble in a fur industry:

(1) Sulfur dye, which may not be removed by treatment.

(2) Grease and alkali (from scouring skins), which clog sewers and retard biological treatment.

(3) Heavy suspended matter.

(4) Toxic chromium (from mineral tar), which prevents digestion of sludge.

(5) Large quantities of organic material with excessive B.O.D.

Metals and wastes from metallurgical and metal working plants are deleterious to sewage treatment, particularly iron, copper, chromium, zinc, and cyanides. Acid iron wastes have caused trouble at Cleveland and Fostoria, Ohio, and at Worcester, Mass. Zinc has retarded sludge digestion at Fostoria, Elyria, and London, Ohio. Chromium up to 25 p.p.m. can be handled, but 40 p.p.m. is disturbing. Cyanides as low as 1 p.p.m. are toxic to biological activities. However, cyanides should not be permitted in a sewer.

The paper cites the concentration limits proposed by the Allegheny County Sanitary Authority (Report, Jan., 1948):

Concentration Limits of Toxic Substances, in P.P.M.

Names of Items	Primary Treatment		Secondary Treatment
	No Sludge Digestion	Sludge Digestion	
Total Iron	5.0	5.0	5.0
Copper	3.0	1.0	1.0
Chromium	5.0	5.0	3.0
Cyanide	2.0	2.0	2.0
pH Index (not less than)	5.0	6.5	6.5

The Authority also recommends that mineral oils be excluded from municipal sewers, soluble oils be reduced by pre-treatment, combustibles be excluded by ordinance, free mineral acid be neutralized at the sources, and acetylene generation sludge be excluded. The author endorses these limits as reasonable. He discusses the remedies for excessive concentration of industrial wastes at sewage treatment plants, such as removal from the sewer and separate treatment; pre-treatment; and acceptance of the waste and enlargement of the plant. Cited are nine examples of headaches, and general recommendations for reducing objectionable constituents at source.

In the discussion, J. A. McCarthy discusses experimental work on industrial wastes, the effect of formaldehyde on filters, and the effect of detergents and wastes high in peroxides and chlorine. Grease and fish scales in salt water are troublesome.

Also in discussion, C. N. Sawyer touches on six needs:

1) Adequate ordinances governing disposal of toxic and other deleterious materials;
2) Adequate sewer rental laws;
3) Controlled discharge and adequate mixing of certain industrial wastes;
4) Study of nutritional factors when certain wastes are involved;
5) Study of existing sewage treatment facilities to determine their shortcomings; and
6) Industrial waste surveys to determine abnormal losses.

Sawyer cites losses which should not be exceeded; paper making, 1 lb. fiber per ton of paper; packinghouse, 1 lb. grease, 3.5 lb. N, and 28 lb. of B.O.D. per ton of kill.

LANGDON PEARSE

Subsurface Sewage Disposal. By J. E. KIKER, JR. *Bulletin No. 23.* Florida Engineering and Industrial Experiment Station (December, 1948). 72 pp., diagrams.

This bulletin was prepared to furnish details of subsurface sewage disposal units normally requiring approval of the State Board of Health.

Estimates of flow are given for various types of establishments, also for sources and fixtures at country clubs and parks. House sewers are discussed, with grades, from 4 to 12-in. diam. Septic tank capacities start with a minimum of 1-day capacity for flow under 2,000 g.p.d., rising to 0.5-day for flows over 6,000 g.p.d. Imhoff tanks are preferred for flows from 10,000 to 100,000 g.p.d. Specifications for construction are given, with information on cleaning. Storm and roof water should be kept out. The liquid effluent should be discharged into an absorption field. The percolation test of soil is described in detail, with coefficients. Details of construction are outlined.

Grease traps on kitchen lines are recommended and described, also dosing tanks.

Sand filter trenches are suggested where soil is non-absorptive.

Subsurface sand filters and superficial sand filters may sometimes be advantageous.

Chlorination of effluent may be needed to protect bathing beaches. Rules for permits, plans, and engineering services occupy 17 pp., including notes on realty subdivisions. A minimum lot of 0.25 acre is recommended where private water supply and sewage disposal are used on a lot, under ideal conditions. Other types of disposal are noted from U.S.P.H.S. Reprint No. 2461.

LANGDON PEARSE

Performance of Recirculating Plant for the Purification of Cannery Wastes in Biological Filters. By DENIS DICKINSON. *The Surveyor*, **108**, 89 (Feb. 11, 1949).

A change in the products handled at a cannery located in a rural district nec-

essitated the provision of adequate treatment facilities. The plant as built consists of sedimentation tanks, trickling filters, humus tank, and pumps and piping for recirculation of final effluent through the filters. The design of the filters was based on an average B.O.D. of 1,300 p.p.m. and a flow of 12,000 g.p.d., discharged over a period of 10 hr. Dilution in the ratio of 5 parts final effluent to 1 part raw waste is provided. It was later decided to extend the period of application to 12 hr. per day. With 1,750 cu. yd. of medium the rate of application is approximately 3.4 gal. (Imp.) per cu. yd. per hr.

The filters are 6 ft. deep, with limestone medium. The stone is graded with 2 ft. of 2-in. material on the bottom, then 2 ft. of 1½-in., 1½ ft. of 2-in. and a 6-in. surface layer of large clinker.

During 1948 the B.O.D. of the effluent ranged from 11 to 21 p.p.m., based on monthly averages. The dissolved oxygen averaged about 90 per cent of saturation.

T. L. HERRICK

Installations for the Treatment of Sewage in Institutional Communities in Sao Paulo, Brazil. BY J. P. JESUS NETO. *Boletim* de Reparticao de Aguas e Esgotos (Sao Paulo). 10th Year. No. 20 (April, 1948).

Final disposal of sewage discharged by small communities situated in unsewered areas constitutes a problem of considerable importance. These communities include structures of various types situated in suburban and rural zones, such as schools, public or private institutions, industrial establishments, hospitals, barracks, and small residential groups. The problem is increasingly more important when it refers to hospital institutions, as the sewage has, because of its nature, a high suspicion from the hygienic point of view. A discussion follows of hospital sewage and contagious diseases transmittable by it, and pollution of surface and subsurface waters. Legislation and official control of these small localities is described with special reference to the problems as handled by the R.A.E. R.A.E. has in operation or under construction 10 such small sewage installations, for communities with populations ranging from 1,000 to 6,000 persons.

Three basic elements are considered of primary importance—volume of flow, composition of sewage, and conditions required in the final effluent. The average composition of raw institutional sewage is generally represented as:

	P.P.M.	Per Cent Volatile
Total solids	930	65
Suspended solids	360	85
Dissolved solids	570	40
B.O.D. (5-day, 20° C.)	350	

Final discharge is invariably into the nearest water course, which seldom satisfies the requirements for simple primary treatment. The method in vogue in the R.A.E. is complete treatment plus final disinfection by automatic calcium hypochlorite feeders.

In certain cases the primary sedimentation is carried out in Imhoff tanks; in other cases, in separate sedimentation and digestion units. For the secondary phase there has been adopted as a general rule the biological system, operated by: (1) open filters, conventional type; (2) covered aero-filters with forced ventilation; and (3) activated sludge with mechanical aeration. Preference is given to covered aero-filters with forced ventilation, but without recirculation. The activated sludge projects in construction are of 2 types according to population—(1) aerators and clarifiers functioning as one unit, and (2) independent aeration tanks. All installations are provided with manually operated screens and grit chambers and with open air sludge drying beds.

In one project under construction (Airport of Sao Paulo) it is proposed to install a comminutor, for floating solids in influent. In the plant for the Tuberculosis Hospital and Invalid Asylum, at Jacana, gas is collected and used in the hospital laboratories.

E. B. BESSELIEVRE

Flax Retting with Aeration. *Technical Paper No. 10.* WATER POLLUTION RESEARCH LABORATORY, Dept. of Scientific and Industrial Research, London, Eng. 146 pp. 1948.

This book outlines methods of retting flax; experiments, both successful and unsuccessful, to treat and to re-use retting liquors; and small plant and full-size plant studies of the most promising methods of re-using the liquors.

In anaerobic retting, bundles of flax are placed in tanks of warm water and allowed to remain approximately a week. The water extracts soluble constituents from the straw and the bacteria originally present in the flax, or added to the tank, break down the pectin and other substances surrounding the fiber. The liquor at the end of a ret is foul smelling, has a 5-day B.O.D. (at 18.3° C.) ranging generally from 1,600 to 2,700 p.p.m., an oxygen absorbed value (from acid N/80 permanganate in four hours at 26.7° C.) ranging from 520 to 980 p.p.m., and runs from 5,000 to 8,000 gallons per ton of deseeded flax retted. The liquor is strongly acid, with a pH of from 4.5 to 5.4, and can seldom be re-used without treatment, as it contains substances that would inhibit the desired bacterial growth.

A chapter is devoted to a review of literature on methods of retting and factors involved and some experiments on disposal or re-use of the retting liquor.

Experiments at the Pollution Research Laboratory on treatment of diluted retting liquors in small percolating filters dosed at a rate of 54 to 58 gal. per cu. yd. per day showed that with neutralized liquor the B.O.D. could be reduced from 220 to approximately 18 p.p.m., but when the B.O.D. was over 300 p.p.m. it was difficult to produce an effluent with a B.O.D. of less than 26 p.p.m.

Experiments with chemical coagulants showed that by using large quantities (for example, 1,260 p.p.m. lime and 1,800 p.p.m. $FeSO_4$) reductions of about 50 per cent in polluting character were obtained. Biological treatment was still required before discharge, to a stream.

In 1942 experiments were conducted on a small-plant scale to determine if anaerobic retting liquor could be re-used. Averages of results follow:

Waste	Oxygen Absorbed (p.p.m.)	5-day B.O.D. 18.3° C. (p.p.m.)	pH Value Range
Leach liquor	990	1130	6.3–6.7
Ret liquor (after leach)	390	2200	4.7–4.9
Ret liquor (with no leach)	690	2040	4.5–5.4

During the course of these rets, attempts were made to re-use the liquors. The liquor could be re-used satisfactorily for as much as three times with only one straw, the B.O.D. for most straws after two rets reaching 4,000 p.p.m., and the period required to complete a ret increasing to over 100 hours.

Experiments on circulating liquors from the retting tank through filters and humus tanks showed that it was impossible to obtain low B.O.D.'s. Both filters were then used in parallel and the rate of application, started at 60 gal. per cu. yd. per day, was increased by stages to 200. At the end of 24 rets, the B.O.D. of the retting liquor was only 125 p.p.m. and that of the mixed settled effluent from the filters was only 6 p.p.m. Biological film on the top three inches of filter media was small. This latter series showed that successive batches could be retted with no discharge of waste waters and that at the completion of any ret the liquor could be circulated through the filter and discharged to a stream.

Further tests were made to find the minimum filter volume that could be used. It was concluded that about 4 cu. yd. of filtering media was needed to treat retting liquors from approximately 160 lb. of deseeded flax. Cost of a system to treat wastes from a typical plant having four tanks, each with a capacity of 4 tons, was estimated to range from 4,000 to 7,000 Pounds (1942–43).

Several series of tests were made recirculating liquor through aeration tanks to determine roughly how much air and recirculation would be needed. At the end of the series, 56 rets, the B.O.D. was 4,280 p.p.m. Flax was darker than that from anaerobic retting, but the quality was satisfactory. Further full scale experiments showed that the liquor was acid and that the B.O.D. could not be materially reduced.

While tests with filters and separate aeration tanks were going on, it was found in small-scale experiments that successive batches could be retted with no discharge of wastes if the liquors were directly aerated in the retting tanks. In the first trial in which frothing of the liquid interfered, it was found that the condition could be controlled by adding a few drops of oil or octyl alcohol. In a second series,

40 successive batches were retted with no discharge or accidental loss of liquor. Concentration of the liquor increased rapidly and the B.O.D. reached 5,150 p.p.m. on the tenth ret and 7,000 p.p.m. on the twenty-sixth. At the end of the series the B.O.D. was 3,000 p.p.m., total solids 12,680 p.p.m., and the pH 7.7. Retting proceeded satisfactorily and the average duration was 70 hours. Air was applied at the rate of 1.2 c.f.m. Neither the quality of the fiber nor of the liquor was improved by the addition of lime during the retting process.

To find the optimum rate of air at which the duration of the retting period would be a minimum and the condition of the liquor remain satisfactory, six series were run. Air supplied at rates of 0.5 and 1 c.f.m. gave generally unsatisfactory results, but satisfactory results were obtained when sufficient air was supplied to maintain a substantially neutral condition.

In subsequent full-scale experiments, a series of forty rets was made with no discharge of wastes, and only enough warm water was added to compensate for that lost by evaporation or on the removed flax. Temperature was normally 30° C.; weight of straw varied from 2 to 4 tons, averaging about 3 tons. Ratio of the weight of water to flax varied from 32:1 to 16:1, the average being about 22:1. Average duration of the rets was about 60 hours. Liquor was stored in two tanks at intervals between rets, a considerable amount of solids depositing on the floor of these units. A partial tabulation of the results follows:

Ret Number	O_2 Absorbed 4 hrs., 26.7° C. (p.p.m.)	5-day B.O.D. 18.3° C. (p.p.m.)	pH	Tot. Solids (p.p.m.)
1	630	1,330	5.4	3,550
4	960	2,600	6.9	6,690
10	1,450	5,300	6.1	10,870
15	1,340	4,500	6.2	10,740
20	1,720	5,400	6.5	13,800
30	1,620	8,200	6.4	15,140
40	1,910	7,450	6.8	17,000

Acidity varied according to the crop of straw used and the weight of flax in the tank. Straw from 26 crops was used, the average yield being 13.2 per cent and the grading satisfactory.

WM. A. HASFURTHER

Course for the Information and Improvement of Operators and Assistants in the Treatment of Sewage. *Boletim* de Reparticao de Aguas e Esgotos (Department of Water and Sewage), Sao Paulo, Brazil. 10th Year. No. 20 (April, 1948).

Instruction and improvement of personnel appointed to exercise the functions of a water and sewage service always receives the attention and interest of the administration of the Reparticao de Aguas e Esgotos (R.A.E.). R.A.E., which maintains several types of treatment plants, considers it important to have operators reasonably well prepared and with initiative to attend to their duties and satisfy the requirements.

In 1945 there was organized for the first time in Brazil (and probably in South America) a course for the instruction and improvement of operators and assistants of sewage treatment works, not only for those charged with the treatment, but also for others interested in the subject.

The course consists of three parts: one for those having a fundamental course in sanitary technique and who wish to specialize in the direction, maintenance, and operation of sewage treatment plants; the second for common operators of small plants or plants where a class A operator is in charge; and the third for assistant operators.

E. B. BESSELIEVRE

Digester Operates as Imhoff Tank During First-Stage Development. BY G. T. SPARROW. *Engineering News-Record*, **142**, 21, 63 (May 26, 1949).

An influent-effluent, weir-trough channel with a movable bottom converted a rectangular digester to an Imhoff tank in step-by-step development of sewage treatment facilities at White Salmon, Wash. The design permits reversal of flow, eliminates cross current between the two parallel clarifier sections, prevents difficulties with heavier settleable solids, and helps take care of the floating solids.

Stage construction of the plant began with what is eventually to be a 15 × 22-ft. digester, 22 ft. deep. Present treatment is provided by installation in the digester of timber baffles to convert it to an Imhoff tank. Good primary effluent is produced by the unit with a minimum of maintenance.

H. P. ORLAND

Average Composition of the Sewage of the City of Villa Maria, Cordoba Province, Argentina. *Revista de Obras Sanitarias de La Nacion* (Buenos Aires). 12th Year. No. 126 (June, 1948).

Results are presented of a study to determine whether to build a new sewage treatment plant or to modify an existing one for this city of 35,000 population, of whom 24,700 are connected to sewers. Tabular data are given for samples taken at 6-hr. intervals over a period of 14 days, and for a weighted, composite sample proportionate to the flow in the separate system at the sample periods. The basic analyses provided the following general characteristics on samples taken between May 30 and June 12, 1948. Flow volume is not given in article, but is probably about 200 liters per capita per day (1.304 m.g.d., or 52.8 g.p.d. per capita for 24,700 sewered population).

Composite Table (assembled by abstractor)

Item	Average for Period	Daily Range		Weekly Range	
		Max.	Min.	Max.	Min.
Total residue by evap. (p.p.m.)	889	991	749	981	775
Fixed solids (p.p.m.)	586	622	544	680	511
Volatile solids (p.p.m.)	303	386	200	354	264
Susp. solids, total (p.p.m.)	113	173	44	130	85
Susp. solids, fixed (p.p.m.)	26	41	10	32	17
Susp. solids, volatile (p.p.m.)	87	132	34	100	66
Settleable solids, 2 hr. (c.c.)	0.8	1.7	0.8	1.0	0.5
Chlorides, as Cl (p.p.m.)	63	73	55	67	57
Sulphates, total, as S (p.p.m.)	0	0	0	0	0
Nitrogen, organic (p.p.m.)	9.8	13.7	5.8	11.3	7.7
Nitrogen, ammoniacal (p.p.m.)	23.6	27.6	21.1	25.7	21.6
Nitrogen, as nitrite (p.p.m.)	0.09	0.23	0.01	0.31	0.03
Nitrogen, as nitrate (p.p.m.)	0.08	0.18	0.05	0.17	0.0
Dissolved oxygen (p.p.m.)	2.1	4.8	0.9	3.0	1.1
B.O.D., 5-day 20° C., raw. (p.p.m.)	150	250	68	165	115
B.O.D., 5-day 20° C., settled 2 hr. (p.p.m.)	120	185	58	155	94
Oxygen consumed, MnO_4K (p.p.m.)	39	58	25	42	36

E. B. BESSELIEVRE

Book Review

Odors: Physiology and Control. By Carey P. McCord and William N. Witheridge. McGraw-Hill Book Company, New York 18, N. Y. First Edition, 1949. $6.50. 405 pp.

This book is claimed to be the first full-length technical book published in the United States dealing exclusively with the subject of odors and their control. An indication of its comprehensive analysis of odor perception, measurement, classification, and regulation is contained in the following list of chapter headings:

The Anatomy of the Olfactory System
The Physiology of the Olfactory Sense
Chemical Constitution and Odors
Odor Classification
Odor Detection and Measurement
The Pathology and Perversions of the Olfactory System
The Influence of Odors on Health and Comfort
Human Body Odors in Health
Human Body Odors in Disease
Odors in the Diagnosis of Disease
Household Odors
Odors of Waters and Foods
Industrial Odors
The Offensive Trades
Air Conditioning and Odors
Chemical and Physical Destruction of Odors
Odor Masking
Odor Cancellation and Counteraction
The Sorption of Odors
Odors as Warning Agents
Odor Repellents and Odor Attractors
The Making of an Odor Survey
The Legal Aspects of Odor Nuisances

Considerable additional material of value is contained in a 125-page bibliography, which is organized to parallel the text content.

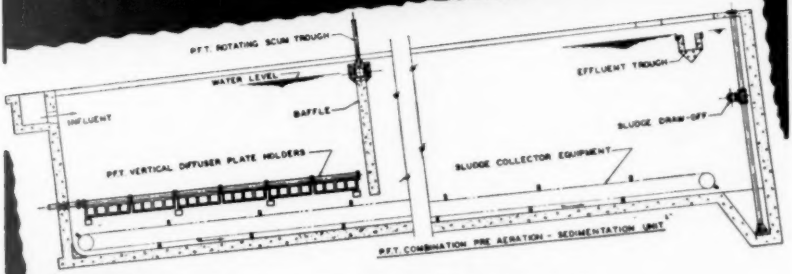
In contrast to earlier works on the same topic, the primary purpose of the present volume is not improvement of perfumes and other pleasant aromas, but revelation of the intricacies of odor physiology and the abatement of noisome odors. Starting with the common ground of odor physiology, the authors early shift their emphasis to the significance and control of offensive odors.

Emphasizing the varied applications of offensive odor control, the book outlines a number of practical methods that may be followed in eliminating odors from factories, homes, public buildings, foods, waters, and the person.

The odor problems of sewage and industrial waste treatment plants are freely referred to throughout the chapters dealing with odor destruction, masking, cancellation, and counteraction, in addition to that on legal aspects. In this latter chapter are given definitions of nuisances, several typical nuisances, an outline of the legal responsibilities of political units, and brief abstracts from outstanding legal cases involving odors. Especially noteworthy is a section of the bibliography on legal cases dealing with odor, wherein are listed several court decisions of interest to sewage treatment plant operators.

H. P. Orland

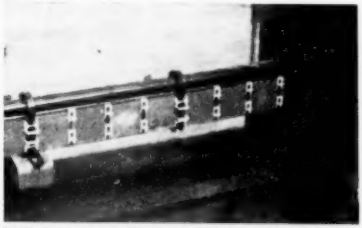
PFT PRE-AERATION



1 . . . PREVENTS SEPTICITY
2 . . . CONDITIONS SOLIDS
3 . . . IMPROVES SETTLING

Here's real economy—the PFT way—in improving primary treatment and increasing settling tank removals. Combination Preaeration-Primary settling tanks are made possible by installing PFT Preaeration equipment in the inlet end of rectangular settling tanks. As shown in the diagram, this equipment is made up of standard porous diffuser plates in vertical cast iron holders arranged for easy removal and servicing of plates. Air introduced through these plates adds oxygen to the raw sewage and provides agitation and mixing. This triple action prevents septicity in the settling compartment and conditions solids for improved settling and a resulting increase in removal of suspended solids and 5-day B.O.D. A baffle wall separates the preareation and sedimentation portion of the tank. A single sludge removal mechanism may be used for both the preaeration and settling portion of tank.

Recent PFT Preaeration equipment installations include: Marshfield, Wis.; San Leandro, Calif.; and Stockton, Calif. The North Point Plant for the City of San Francisco, for which contracts were recently awarded, also incorporates PFT preaeration equipment. Write for details.



PFT Preaeration Equipment in Aeration-Sedimentation tank at Sewage Treatment Plant of the Central Contra Costa Sanitary District, Walnut Creek, Calif.—Clyde C. Kennedy, Consulting Engineers.

PFT

PACIFIC FLUSH TANK CO.

SEWAGE TREATMENT EQUIPMENT EXCLUSIVELY SINCE 1911

4241 RAVENSWOOD AVENUE CHICAGO 13, ILLINOIS

NEW YORK • LOS ANGELES • SAN FRANCISCO • CHARLOTTE, N. C. • DENVER • TORONTO

"Stay out of here folks....
this hot stove will fry you!"

WHEN the first gas range, with its promise of a cool kitchen, was exhibited at the Philadelphia Centennial Exposition in 1876, little did its sponsor dream of a market of 21,000,000 homes. For that is the extraordinary number of residential customers now served by gas for cooking, refrigeration, or home heating.

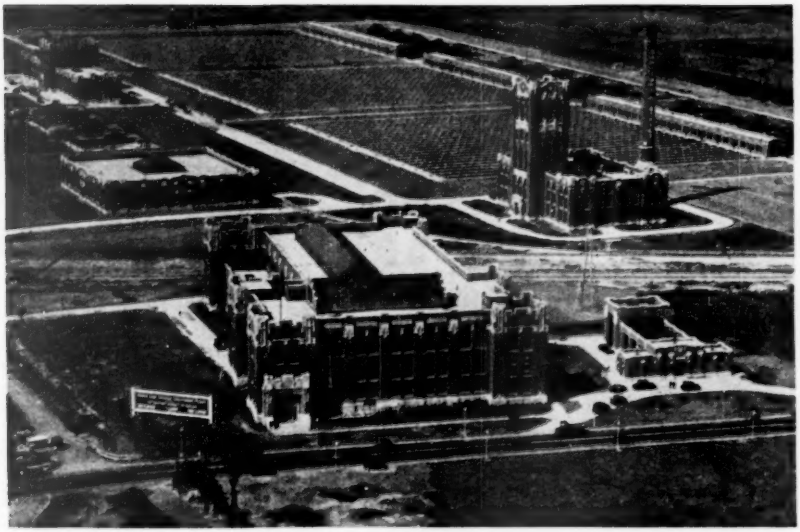
Water supply and sanitation also made extraordinary progress in the half-century since 1899, the year our Company was established. Today, 12,000 water works furnish 85 million people with a dependable supply of safe, palatable water. Over 6,000 sewage treatment plants contribute to the health of the nation.

In these three progressive branches of public service—gas, water supply and sanitation—are customers who have been buying pipe from us for 50 years. They know that we, also, have made signal progress, from decade to decade, in developing and perfecting better methods for the production of better pipe.

To those responsible for the great progress in water supply, gas and sanitation service and their contribution to better health and living over the past fifty years, America pays tribute.

U.S. CAST IRON PIPE

1899-1949
U. S. Pipe & Foundry Co.
Makers for 50 years of cast iron pipe for water, gas and sewerage service.
General Offices: Burlington, N. J.



In large activated sludge sewage plants (such as those of the Chicago Sanitary District) and in small installations, too, Norton Porous Plates or Tubes are selected for maximum efficiency and minimum costs in air diffusion. During manufacture the closest control is exercised over such important qualities as permeability, porosity, pore size and wet pressure loss. These Porous Mediums are physically strong, chemically stable and resistant to heat. They are constructed to deliver air to the sewage in amounts and at flow rates calculated to give the best results.

For complete information
write for Catalog No. 1246.

NORTON COMPANY **Worcester 6, Mass.**

NORTON **Porous Plates and Tubes**®

Less Infiltration

TRANSITE* SEWER PIPE offers two basic safeguards that minimize infiltration in sewer lines: *tighter* joints and *fewer* joints.

Transite's special sleeve-type joints make up tight and stay tight in service.

Its long 13-foot lengths reduce the number of joints in the system.

These safeguards cut down the volume usually allowed for infiltration, reducing sewage load on the treatment plant and conserving plant capacity for future needs. Where new treatment facilities are planned, this reduced infiltration may permit consideration of a smaller plant with resulting economies.

Other Transite Economies—Transite's long lengths help maintain uniform grades; fewer joints reduce turbulence in the line. These advantages, added to Transite's unusually smooth interior, mean better flow qualities (Kutter's N=.010). This often permits designing the system with flatter grades and shallower trenches. Or, as an alternate economy, pipe of smaller diameter may be specified.

Transite Sewer Pipe is made of asbestos, cement and silica by a special manufacturing process that employs steam curing to develop greater corrosion resistance and strength. It is available in four strength classes in sizes to 36", permitting selection of the pipe best suited to trench conditions, and frequently eliminating the need for concrete cradles.

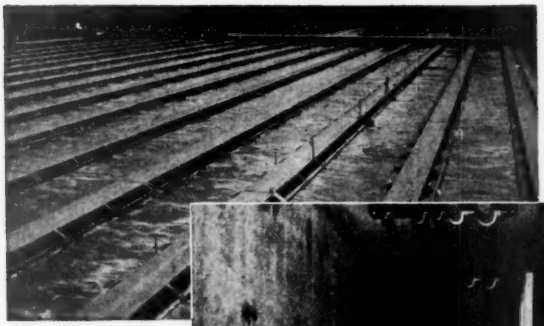
For further details, write Johns-Manville, Box 290, New York 16, N. Y.

JM

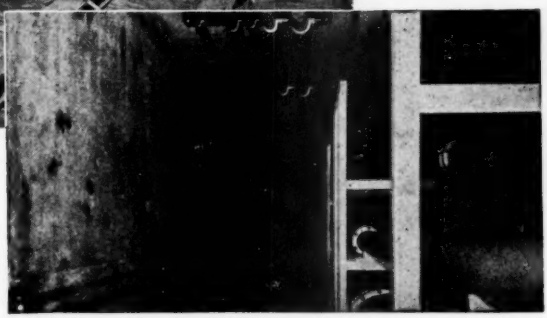
*Transite is a Johns-Manville registered trade mark

. . . Johns-Manville

TRANSITE SEWER PIPE . . .



Everdur Electrical Conduit serves the aeration and final settling tanks in bringing power from the operating galleries to the sluice gates of the control centers, and from these centers to the operating mechanism on the center pier of each tank.



Everdur Electrical Conduit in service tunnel looking north from north gallery.

PERFORMANCE

in World's Largest Sewage Treatment Plant

. . . leads to extended use of Everdur Electrical Conduit

WHEN Chicago's Southwest Sewage Treatment Plant was built 13 years ago, it utilized 14 miles of Everdur* Electrical Conduit, in sizes from ¾" to 2½". Conduit of Everdur Metal was selected because of its high physical properties and excellent resistance to many corroding agents.

More and more Everdur Conduit went into this plant, as its 1939 capacity of 400 m.g.d. was expanded to 1,000 m.g.d. by mid-1948. Further expansion will take place over the next 5 years. Considerable Everdur Conduit is specified in several new contracts awarded to the Northern States Electric Company, Chicago.

For detailed information on Everdur Copper-Silicon Alloys in Sewage and Water Works service, write for Publications E-11 and E-5.

*Reg. U. S. Pat. Off.

ANACONDA

Everdur

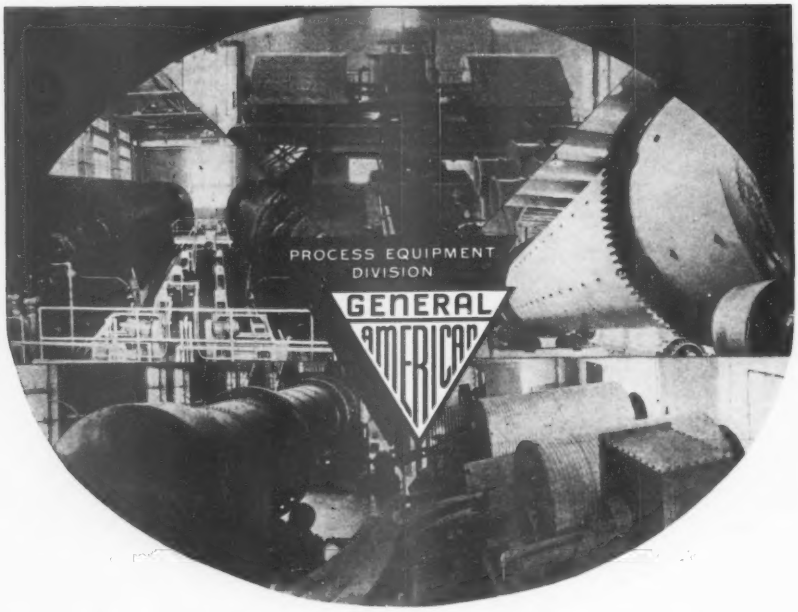
COPPER-SILICON ALLOYS

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut

Subsidiary of Anaconda Copper Mining Company

In Canada: ANACONDA AMERICAN BRASS LTD., *New Toronto, Ont.*



Modern Sewage Treatment Plants

require equipment that has proved itself efficient and is backed by individual responsibility for design, engineering, fabrication and initial operation.

General American Conkey Sludge Filters—the first to be used for large scale dewatering of sludges such as primary, elutriated-digested, Guggenheim Process, etc. — are dewatering more than a thousand tons of dry solids daily.

General American Louisville Dryers have been successfully used for years drying both activated and digested sludges. Type "L", with patented fire-conduits to eliminate scorching or burning, produces a uniformly high quality maximum yield of dried product for fertilizer or earth conditioner.

Let the experience and knowledge of General American engineers help you while your plans are in the blue print stage.

Other
GENERAL AMERICAN EQUIPMENT

SLUDGE DRYERS	*STORAGE TANKS*
SLUDGE GASHOLDERS	*THICKENERS*
TURBO-MIXERS	*SCREENING DEWATERERS*

GENERAL AMERICAN TRANSPORTATION CORPORATION

Process Equipment Division

SALES OFFICE: 10 East 40th St., Dept. 830a, New York 17, N. Y.

WORKS: Sharon, Pa., East Chicago, Ind.

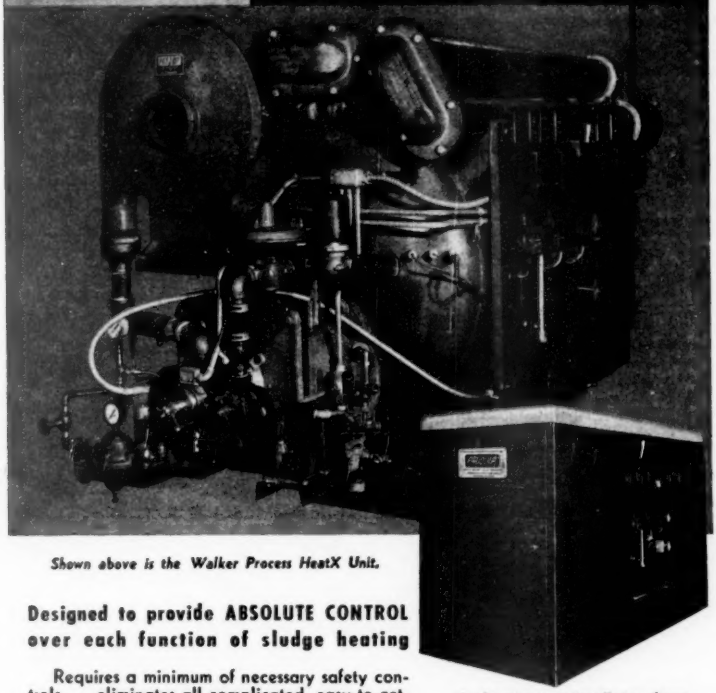
TRADE MARK

OFFICES: Chicago, Cleveland, Louisville, Orlando, Pittsburgh, St. Louis, Sharon, Washington, D. C.

WALKER PROCESS

HEATX UNIT

Digester Heat Exchanger



Shown above is the Walker Process HeatX Unit.

Designed to provide ABSOLUTE CONTROL over each function of sludge heating

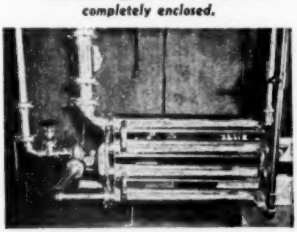
Requires a minimum of necessary safety controls . . . eliminates all complicated, easy-to-get-out-of-order "gadgets".

Each function is separate . . . easily and accurately controlled.

Sludge pumps provide forced circulation of sludge from digester through heater tubes, and the hot water pump forces uniform flow of jacket water to maintain desired heated sludge temperatures under highly efficient turbulent flow conditions.

This versatile HeatX Unit is adaptable to all existing installations . . . without changing present boiler. We'll gladly supply complete details.

Combination type installation shown completely enclosed.



Walker Process HeatX Unit installation.

WRITE FOR BULLETIN 24S24

WALKER PROCESS EQUIPMENT INC.

PROQUIP EQUIPMENT • EQUIPMENT ENGINEERING

Aurora • Illinois

DIRECTORY OF ENGINEERS

(Continued on page 34)

ALBRIGHT & FRIEL, INC.
FRANCIS S. FRIEL
Consulting Engineers
WATER, SEWAGE AND INDUSTRIAL WASTE PROBLEMS
AIRFIELDS, REFUSE INCINERATORS
INDUSTRIAL BUILDINGS
CITY PLANNING VALUATIONS
REPORTS LABORATORY
Suite 1509-18 121 S. Broad St. PHILADELPHIA 7

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick Louis R. Howson
Donald H. Maxwell
Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation
Civic Opera Building Chicago

BAXTER, NELSON & WOODMAN
Civil and Sanitary Engineers
Water Supplies Water Treatment
Sewer Systems Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 67 Crystal Lake, Illinois

ONLY $48 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage works field and will afford maximum prestige!

BLACK & VEATCH
Consulting Engineers
4706 Broadway, Kansas City 2, Mo.
Water Supply Purification and Distribution; Electric Lighting and Power Generation, Transmission and Distribution; Sewerage and Sewage Disposal; Valuations, Special Investigations and Reports.

CLINTON L. BOGERT ASSOCIATES
Consulting Engineers
CLINTON L. BOGERT IVAN L. BOGERT
J. M. M. GREIG ROBERT A. LINCOLN
DONALD M. DITMARS ARTHUR P. ACKERMAN
Water and Sewage Works
Refuse Disposal Industrial Wastes
Drainage Flood Control
624 Madison Ave, New York 22, N. Y.

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewerage—Sewage Treatment
Water Supply—Purification
Refuse Disposal—Analyses
Municipal —Industrial Projects
Valuations—Reports—Designs
110 William Street New York 7, N. Y.

BUCK, SEIFERT AND JOST
Consulting Engineers
(FORMERLY NICHOLAS S. HILL ASSOCIATES)
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street New York 3, N. Y.

BURGESS & NIPLE
Civil and Sanitary Engineers
Water Supply and Purification
Sewerage and Sewage Treatment
584 East Broad Street
Columbus 15, Ohio

Take advantage of the services of these outstanding consultants!

BURNS & McDONNELL ENGINEERING CO.
Consulting Engineers 50th year
Waterworks, Light and Power, Sewerage, Reports, Designs, Appraisals, Rate Investigations.
Box 7088, Country Club P.O. Station
Office 95th and Troost
Kansas City 2, Mo.

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS — Designs and Surveys, Planning, Bridges
WATER WORKS — Roads and Streets, Airports, Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification, Sewerage Systems, Sewage and Industrial Waste Treatment, Power Development and Applications, Investigations and Reports, Valuations and Rates.
210 E. Park Way at Sandusky, Pittsburgh 12, Pa.

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
351 East Ohio St. Chicago 11, Ill.

OSCAR CORSON
Consulting Engineer
Sewage and Industrial Waste Problems
Drainage—Water Supply—Airfields
Plans—Supervision—Surveys
902 Highland Avenue Ambler, Pa.

DE LEUW, CATHER & COMPANY
Water Supply — Sewerage
Railroads — Highways
Grade Separations—Bridges—Subways
Local Transportation
Investigations — Reports — Appraisals
Plans and Supervision of Construction
150 North Wacker Drive, Chicago 6
505 Colorado Bldg., Washington 5

FAY, SPOFFORD & THORNDIKE
ENGINEERS
CHARLES M. SPOFFORD, JOHN AYER, BION A. BOWMAN, CARROLL A. FARWELL, RALPH W. HORNE, WILLIAM L. HYLAND, FRANK L. LINCOLN, HOWARD J. WILLIAMS
Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment—Airports
Investigations and Reports — Designs
Supervision of Construction — Valuations
Boston New York

FULTON & PFEILER
Consulting Engineers
Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control
3209 Brown Road Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS
Water Works—Sewage
Industrial Waste & Garbage Disposal
Roads—Airports—Bridges & Flood Control
Town Planning Appraisals
Investigations & Reports
Harrisburg, Pa. — New York, N. Y.
Scranton, Pa. — Pittsburgh, Pa.

GILBERT ASSOCIATES, INC.
Engineers and Consultants
Power Plant Engineering
Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
New York, Houston — READING, PA. — Washington, Philadelphia

IVAN M. GLACE
Consulting Sanitary Engineer
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal
Design, Construction, and Supervision of Operation
N. Front & Boas Sts. Harrisburg, Penna.

It pays to secure competent and experienced engineering advice!

WILLIAM A. GOFF, INC.
General Engineering and Consulting Services
Water, Sewerage, Refuse Incineration
Industrial Buildings, Power Plants
Airports, Town Planning
Plans, Supervision, Valuations, Reports
Broad St. Station Bldg., Philadelphia 3, Pa.

GREELEY & HANSEN
Engineers
Samuel A. Greeley — Paul Hansen (1920–1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke
Water Supply, Water Purification
Sewerage, Sewage Treatment
Flood Control, Drainage, Refuse Disposal
220 S. State Street, Chicago 4

HAVENS AND EMERSON
Consulting Engineers
W. L. Havens — C. A. Emerson
A. A. Burger — F. C. Tolles — F. W. Jones
Water, Sewage, Garbage, Industrial Wastes, Valuations.—Laboratories
Leader Bldg. — Cleveland 14
Woolworth Bldg. — New York 7

HAYDEN, HARDING & BUCHANAN
Consulting Engineers
John L. Hayden — John H. Harding
Oscar J. Campia
Water Works—Sewerage
Civil—Mechanical
Electrical—Structural
826 Park Square Building, Boston, Mass.

HORNER & SHIFRIN
Consulting Engineers
W. W. Horner — S. W. Jens
H. Shifrin — E. E. Bloss
V. C. Lischer
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

JONES, HENRY & SCHOONMAKER
(Formerly Jones & Henry)
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. — Toledo 4, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, N. Y. — FT. LAUDERDALE, FLA.

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design, Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

MORRIS KNOWLES, Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. — Pittsburgh 22, Pa.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street — Rochester 4, N. Y.

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory — Valuations
Airfields
Statler Building
Boston 16

Parsons, Brinckerhoff, Hall & Macdonald
G. Gale Dixon, Associate
Engineers
Dams, Water Works, Sewerage
Airports, Bridges, Tunnels
Traffic & Transportation Reports, Highways
Subways, Foundations, Harbor Works, Valuations
Power Developments — Industrial Buildings
51 BROADWAY, NEW YORK 6, N. Y.

Take advantage of the services of these outstanding consultants!

BOYD E. PHELPS, INC.
Architects and Engineers
Water Supply and Purification
Sewerage and Sewage Treatment
Power Plants, Buildings, Investigations,
Reports, Appraisals, Rate Studies
232 Franklin Street Michigan City, Indiana

MALCOLM PIRNIE ENGINEERS
Civil & Sanitary Engineers
MALCOLM PIRNIE ERNEST W. WHITLOCK
ROBERT W. SAWYER G. G. WERNER, JR.
RICHARD HAZEN
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 W. 43rd St. New York 18, N. Y.

RIPPLE AND HOWE
Consulting Engineers
O. J. RIPPLE B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports.
426 Cooper Bldg. Denver 2, Colorado

RUSSELL and AXON
Consulting Engineers
Geo. S. Russell
Joe Williamson, Jr. F. E. Wenger
Sewerage, Sewage Disposal, Water Supply, Water Purification, Power Plants, Appraisals, Rate Investigations, Reports, Plans, Specifications.
408 Olive St. Municipal Airport
St. Louis 2, Mo. Daytona Beach, Fla.

STANLEY ENGINEERING COMPANY
Sewerage—Waterworks
Drainage—Flood Control
Electric Power—Airports
Hershey Building
Muscatine, Ia.

ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Mechanical Structural
Surveys Reports Appraisals
209 S. High St. Columbus 15, Ohio

WESTON & SAMPSON
Consulting Engineers
Water Supply, Water Purification,
Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil—Sanitary—Structural
Mechanical—Electrical
Reports, Plans, Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

Cathodic PROTECTION is More Than Equipment

You can purchase good cathodic protection *equipment* from many reputable manufacturers of anodes, rectifiers, etc. But that's only half the answer to rust and corrosion problems. The rest of it is technical skill in the *application* of cathodic protection equipment and theory.

Electro Rust-Proofing has, at your disposal, a trained staff of corrosion specialists ready to give each problem the individual attention required for successful solution. Why not write today? There's no obligation.

ELECTRO RUST-PROOFING CORP., (N. J.)
BELLEVILLE 9, NEW JERSEY
REPRESENTED IN PRINCIPAL CITIES E-11

Only

CLOROBEN

Will do all of this—

Inhibit hydrogen sulfide and slime growth.

Stop odor complaints and H_2S corrosion of sewer lines and plant equipment.

Banish insects from the sewer lines and plant.

Reduce the E. coli count.

Increase the efficiency and capacity of the treatment plant.

Whatever your disposal problem, write for the Cloroben Manual.

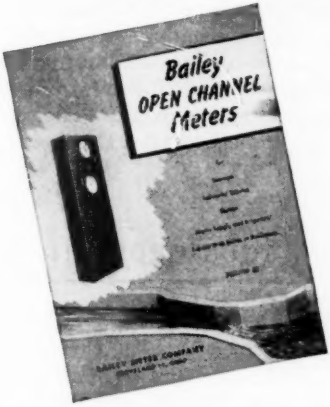
THE CLOROBEN CORPORATION
15 EXCHANGE PLACE JERSEY CITY 2, N. J.

The Pioneers of Up-Sewer Treatment

For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

Two new publications

NOW AVAILABLE . . .

★ GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING

An authoritative volume of extensive value to everyone in the engineering profession. The Glossary contains 276 pages, 4,200 terms and cross references pertaining to nomenclature of hydrologic, hydraulic, and sewage works fields. Endorsed and compiled by ASCE, AWWA, APHA, and FSWA. Price to members $1.00 in paper cover, $2.00 in cloth.

★ UNIFORM SYSTEM OF ACCOUNTS FOR SEWER UTILITIES

A special publication containing information on systematic administration of sewage works through accounting. Adapts to sewage works the accounting system proved successful in transportation, water works, power and gas utilities. The Accounting Manual was prepared by the FSWA Sewage Works Practice Subcommittee on Sewage Works Accounting, contains 117 pages, mimeographed, price $5.00.

MEMBERS . . . SEND IN YOUR ORDER TODAY!

FEDERATION OF SEWAGE WORKS ASSNS.
325 ILLINOIS BLDG., CHAMPAIGN, ILL.

Please forward the following publications as indicated.

☐ Copies GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING, paper cover @ $1.00 each.

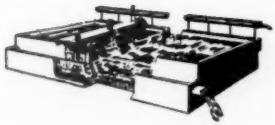
☐ Copies GLOSSARY—WATER AND SEWAGE CONTROL ENGINEERING, cloth cover @ $2.00 each.

☐ Copies ACCOUNTING MANUAL (mimeographed) @ $5.00 each.

NAME.....

ADDRESS.....

CITY..... STATE.....



"Shure, 'n it's a HARDINGE AUTOMATIC BACKWASH SAND FILTER ye'r lookin' at—best sand filter made.

"Cleans it's own filter bed, it does—*while operatin'*—'n all automatic too, I niver touch it.

"It knocks out fine suspended solids from me sewage effluent, after final settlin', slick as a whistle!

"If ye got suspended solids trouble, write Hardinge. Tell 'em to send ye Bulletin AH-382-16."

HARDINGE
COMPANY INCORPORATED
YORK, PENNSYLVANIA — 240 Arch St. • Main Office and Works
NEW YORK 17—122 E. 42nd St. • 205 W. Wacker Drive—CHICAGO 6
SAN FRANCISCO 11—24 California St. • 200 Bay St.—TORONTO 1

Manual of Practice No. 1

"Occupational Hazards in the Operation of Sewage Works"

$.25 each to Federation Members—$.50 each to Non-Members

Manual of Practice No. 2

"Utilization of Sewage Sludge as Fertilizer"

$.75 each to Federation Members—$1.25 each to Non-Members

Manual of Practice Binders

Attractive and practical 3-ring binders, equipped with end-openers, lettered on front cover and back edge and large enough to file several manuals of practice as they will be issued, are ready for delivery now. *Price $2.00.*

Place your orders immediately!

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
325 Illinois Building, Champaign, Ill.

PROOF
OF
"STERELATOR EFFICIENCY"

NO
JOB
TOO
LARGE

SEND
US
COPY
OF
SPECIFICATIONS

Actual Users—THE BEST PROOF OF ALL—
Prove our claims that Everson SterElators are
DEPENDABLE—SAFE—EFFICIENT
Easy to operate at LOW MAINTENANCE COST.

Everson SterElators METER-MIX-FEED
Chlorine gas accurately for all Water
or Sewage Sterilizing demands.

Furnished for Manual or Automatic operation.

Everson SterElators utilize a high Vacuum.
The indicating FLOW METERS have a 10 to 1 ratio.

SterElators by Everson

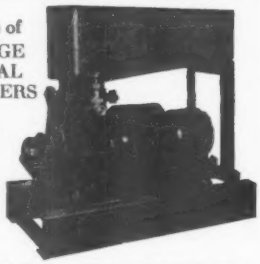
EVERSON MANUFACTURING CORPORATION
207 West Huron Street, Chicago 10, Illinois

"Our 63rd Year"

Serving America

Doing The Things We Know Best

Builders of
GARBAGE
DISPOSAL
SHREDDERS
for the
Merchant
Marine
and
Municipal
Sewage
Plants



SANITARY ENGINEERS

Why Not Investigate the Proven Gruendler Principle?

Send for Catalog and Facts on Latest
GRUENDLER SEWAGE SHREDDERS
for Municipal Sewage Plants

For disintegration of Rag Stock, Garbage, Floatables, and Fibrous Materials with out Choke Down so as to pass Screen Bar—Select a GRUENDLER SHREDDER.

GRUENDLER

CRUSHER & PULVERIZER CO.
2929 N. Market St. St. Louis 6, Mo.

THE
MAGNETITE FILTER

with successful operating records, extending back as much as 16 years, is again available for improving the effluent or increasing the capacity of treatment plants for sewage and trade wastes.

•

MAGNETITE
FILTER CORPORATION
10 EAST 40TH STREET
NEW YORK 16, N. Y.

Are You Interested
in
Sewage and Industrial Waste Treatment?

If so, affiliate with

THE FEDERATION OF
SEWAGE WORKS ASSOCIATIONS

•

For Particulars, Write

FEDERATION OF
SEWAGE WORKS ASSOCIATIONS
325 ILLINOIS BUILDING
CHAMPAIGN, ILL.

How to beat a legal "threat" on WASTE DISPOSAL

With State after State now imposing legal restrictions on industrial waste disposal, you may be faced with this problem quite suddenly. Only by starting to gather complete data now can you be prepared for necessary action when the time comes.

Foxboro has prepared a concise, informative bulletin on how to conduct a waste disposal survey . . . the simple steps to take to gather the necessary data on quantities, concentrations and constituents. Send for a copy of "Waste Disposal Surveys" today. Write **The Foxboro Company, 162 Neponset Avenue, Foxboro, Massachusetts, U. S. A.**

TYPICAL FOXBORO INSTRUMENTS THAT LEAD TO BETTER WASTE DISPOSAL

The Model 40... "the finest modern controller" . . . is the foundation of many outstanding Foxboro Waste Disposal Systems. It is used for the control of flow, pH, conductivity, temperature and other variables.

Foxboro Float and Cable Type Instruments are designed for use on weirs and Parshall flumes. They read directly in flow.

FOXBORO REG. U. S. PAT. OFF. RECORDING · CONTROLLING · INDICATING INSTRUMENTS

TODAY'S FILTER PLANTS use *vitrified clay filter bottom blocks*

Designed by Clarence MacCallum

Special Advantages of TFFI Blocks

WON'T CLOG **LAST A LIFETIME**

EASY TO LAY **RESIST ACIDS**

Great Neck's New DORR Biofilter a fine example of modern design . . .

The Dorr Company can point with pride to this fine example of Biofiltration serving part of Great Neck. An average flow of 1.2 M.G.D. is handled by single stage Biofiltration employing a dual recirculation flow-sheet.

In addition to the Dorr equipment an important feature of this modern plant is its underdrainage system built for life-time, trouble-free service of *Vitrified Clay Filter Bottom Blocks.*

TRICKLING FILTER FLOOR INSTITUTE

AYER-McCAREL-REAGAN CLAY CO., Brazil, Ind. ● NATIONAL FIREPROOFING CORP., Pittsburgh 12, Pa.
BOWERSTON SHALE CO., Bowerston, Ohio ● TEXAS VITRIFIED PIPE CO., Mineral Wells, Tex.
W. S. DICKEY CLAY MFG. CO., Kansas City 6, Mo. ● POMONA TERRA-COTTA CO., Pomona, N. Car.

TESTED..PROVED..APPROVED
Economy
NON-CLOGGING SEWAGE PUMPS
Mixed flow volute. Capacities from 2,000 to 50,000 G.P.M. Heads from 10 to 60 ft.
Non-clogging vertical or horizontal. Capacities from 50 to 20,000 G.P.M. Heads from 10 to 100 ft.
Non-clogging sump. Capacities from 50 to 10,000 G.P.M. Heads from 10 to 100 ft.
In sewage pumping, the Economy line has reached its present excellence through 34 years of development. Case histories of municipal and industrial installations throughout the world prove it. Whatever your pumping requirement, you'll find there's an Economy Pump to do the job better . . . longer . . . at lower cost. For complete details write Dept. AC-7.
Centrifugal, axial, and mixed flow pumps for all applications.
Economy Pumps Inc.
Division of Hamilton-Thomas Corp.
Hamilton, Ohio

SEWER AND PIPE CLEANING EQUIPMENT

Sewer Rods, Wood & Steel — Root Cutters, Buckets
Sewer Machines, Engine Driven & Hand Operated
Steel Tapes, Flushers, Nozzles & Brushes

Send for complete catalog

W. H. STEWART, INC.

P.O. Box 767 — Syracuse, N. Y.

Inertol Protection Means Lowest Cost Per Year
For Concrete and Steel.

INERTOL COMPANY, INC.
FACTORY & HEAD OFFICE
470 FRELINGHUYSEN AVE.
NEWARK 5, N.J.
WESTERN BRANCH
64 SOUTH PARK
SAN FRANCISCO 7, CAL.

Do you have a

MANUAL OF PRACTICE BINDER?

— Keeps FSWA Manuals of Practice filed systematically . . . ready for use . . . in your reference library.

— Large enough for additional manuals to be added.

— Attractively lettered on front cover and back edge for quick identification.

$2.00 each

Send in you order NOW!

FEDERATION OF SEWAGE WORKS ASSOCIATIONS
325 ILLINOIS BUILDING
CHAMPAIGN, ILL.

Please forward.....special ring binders for FSWA Manuals of Practice @ $2.00 each.

NAME .....

ADDRESS .....

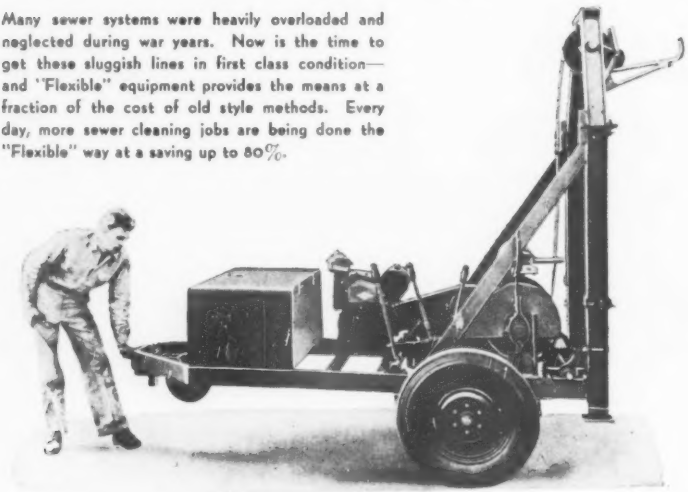
CITY.....ZONE.....STATE.....

"FLEXIBLE"

POWER BUCKET MACHINES

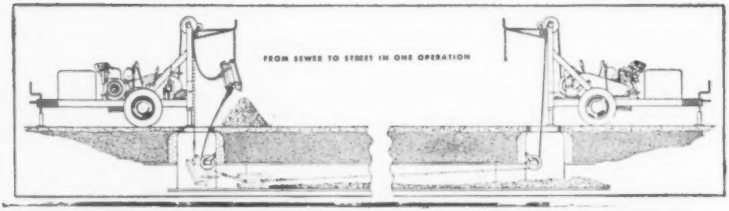
Clean Sewers The "Flexible" Way

Many sewer systems were heavily overloaded and neglected during war years. Now is the time to get these sluggish lines in first class condition—and "Flexible" equipment provides the means at a fraction of the cost of old style methods. Every day, more sewer cleaning jobs are being done the "Flexible" way at a saving up to 80%.



FLEXIBLE POWER BUCKET MACHINE

POWER—DEPENDABLE—OPERATION—SPEED—SAFETY—ECONOMY—LONG WORK LIFE



FLEXIBLE SEWER-ROD EQUIPMENT CO.

9059 Venice Blvd., Los Angeles 34, California

141 W. Jackson Blvd. Chicago, Ill.
401 Broadway New York 13
147 Hillside Ter. Irvington, N. J.
P. O. Box 165 Atlanta
2011 Central Ave. Memphis, Tenn.
801 E. Excelsoir Blvd. Hopkins, Minn.
29 Cerdan Ave. Roslindale 31, Mass.
P. O. Box 447 Lancaster, Texas
41 Greenway St. Hamden, Conn.
3786 Durango Ave. Los Angeles 34, Calif.
909 N. Homewood Ave. Pittsburgh 8, Pa.
4455 S.E. 24th Ave. Portland 2, Ore.

INDEX TO ADVERTISERS

	Page
Albright and Friel, Inc.	34
Alvord, Burdick & Howson	34
American Brass Company	31
American Car and Foundry Company	20
American Well Works	23
Armco Drainage and Metal Products, Inc.	14
Bailey Meter Company	39
Baxter, Nelson & Wooldridge	34
Black and Veatch	34
Bogert, Clinton L., Associates	34
Bowe, Albertson & Associates	34
Brown Instrument Company	21
Buck, Seifert & Jost	34
Builders-Providence, Inc.	2
Burgess & Niple	34
Burns & McDonnell Engineering Company	35
Camp, Dresser & McKee	35
Capitol Engineering Corporation	35
Cast Iron Pipe Research Association	24
Chain Belt Company	12
Chapman Valve Manufacturing Company	11
Chester Engineers, The	35
Chicago Pump Company	2
Clorofben Corporation, The	38
Consoer, Townsend & Associates	35
Corson, Oscar	35
De Leuw, Cather & Company	35
Dorr Company, The	26
Economy Pumps, Inc.	44
Electro Rust-Proofing Corp. (N. J.)	17
Everson Manufacturing Corporation	42
Fay, Spofford & Thorndike	35
Flexible Sewer Rod Equipment Company	46
Foxboro Company, The	43
Fulton & Pfeifer	35
Gannett Fleming Corddry & Carpenter, Inc.	35
General American Transportation Corporation	22
General Chemical Division (Allied Chemical & Dye Corp.)	28
Gilbert Associates, Inc.	35
Glace, Ivan M.	35
Goff, Inc., William A.	46
Greeley & Hansen	35
Gruendler Crusher and Pulverizer Company	47
Hardinge Company, Inc.	41
Havens and Emerson	34
Hayden, Harding & Buchanan	36
Hazen & Sawyer	36
Inertol Company, Inc.	44
Infilco, Inc.	13
Jeffrey Manufacturing Company	19
Johns-Manville Corporation	30
Jones, Henry & Schoonmaker	34
Keis & Holroyd	35
Kennedy, Clyde C.	34
Knowles, Inc., Morris	44
Koppers Company, Inc.	10
Link-Belt Company	6
Lozier, William S., Company	34
Magnetite Filter Corporation	42
Metcalf & Eddy	36
National Clay Pipe Manufacturers, Inc.	4
Nichols Engineering & Research Corporation	9
Nordstrom Valve Division (Rockwell Manufacturing Company)	15
Norton Company	29
Pacific Flush Tank Company	27
Parsons, Brinckerhoff, Hall & Macdonald	36
Phelps, Inc., Boyd E.	37
Pirnie Engineers, Malcolm	37
Portland Cement Association	18
Ripple and Howe	37
Rockwell Manufacturing Company	15
Russell and Axon	37
Simplex Valve and Meter Company	8
Stanley Engineering Company	37
Trickling Filter Floor Institute	45
Stilson & Associates, Miles E.	37
Stewart, W. H., Inc.	44
U. S. Pipe and Foundry Company	25
Vapor Recovery Systems Company	16
Walker Process Equipment, Inc.	33
Wallace and Tiernan Company	Back Cover
Weston & Sampson	37
Whitman, Requardt & Associates	37
Wood Company, R. D.	7
Yeomans Brothers Company	19

When writing advertisers, please mention SEWAGE WORKS JOURNAL

LANCASTER PRESS, INC., LANCASTER, PA.

Sewage Treatment Dollars are bigger *with* Chlorination

Chlorination, fitted to your specific needs by W&T Engineers, gives you more treatment facilities per dollar than any other single treatment adjunct. It can be put to work at your plant for less than 1% of total plant cost in most cases. And for that 1%, chlorination by W&T is on the job ready to overcome such troubles as ODORS, PLANT OVERLOAD, FILTER PONDING, GREASE, and SLUDGE BULKING, wherever and whenever they develop.

Of course, to get these results, chlorination must be correctly applied. That's where W&T's 35 years of experience come in. Experience plus sturdy W&T Equipment—designed to take hard intermittent sewage plant use—adds up to one sure fact—that you will have the proper equipment, properly installed, to do a thorough job at low cost.

Call your nearest W&T Representative, now, for complete details on the full line of W&T equipment for effective sewage chlorination.

WALLACE & TIERNAN COMPANY, INC.

CHLORINE AND CHEMICAL CONTROL EQUIPMENT
NEWARK 1, NEW JERSEY • REPRESENTED IN PRINCIPAL CITIES